Volume XXIII ~ Number Four Winter 1944

Bell Telephone MAGAZINE

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American Telephone & Telegraph Company · New York

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"The ideal and aim of the American Telephone and Telegraph Company and its Associated Companies is a telephone service for the nation, free, so far as humanly possible, from imperfections, errors, or delays, and enabling anyone anywhere to pick up a telephone and talk to anyone else anywhere else, clearly, quickly and at a reasonable cost."

A Medium of Suggestion & a Record of Progress

Published for the supervisory forces of the Bell System by the Information Department of AMERICAN TELEPHONE AND TELEGRAPH CO., *195 Broadway, New York 7, N. Y.*
WALTER S. GIFFORD, *President;* ROBERT H. STRAHAN, *Secretary;* DONALD R. BELCHER, *Treasurer*

Who's Who & What's What

in This Issue

LAID END TO END, a hundred million dollars will reach a long way out many a country road and across many a rural acre to extend telephone service to the million farms where the Bell System will seek new customers after the war. The constructive program which so large a sum will be spent to accomplish is described by JOHN J. HANSELMAN and HAROLD S. OSBORNE —who view it with a nation-wide perspective. For Mr. Hanselman is assistant vice president heading the Commercial Division, and Mr. Osborne is chief engineer, of the Department of Operation and Engineering of the A. T. & T. Co. Mr. Hanselman's Bell System career began in 1921, when he entered the rate section of the O. & E.'s Commercial Division as an engineer. The intervening years have seen him as group head in several sections of the Division, sales engineer, rate engineer, and in his present post since late last year. Mr. Osborne joined the A. T. & T Co. in 1910 as an engineer in the then transmission and protection department, and has since been transmission engineer, operating results engineer, plant engineer, and assistant chief engineer. He became chief engineer in 1943. He is the author of more than a score of published scientific and engineering papers, is a past president of the A.I.E.E., and is a fellow of a number of engineering societies.

WHAT PART are the scientists and engineers of Bell Telephone Laboratories playing in this global war? The Army and the Navy know the answers to that question, but the public has had little opportunity to know or learn about the Laboratories' activities. OLIVER E. BUCKLEY, president of the Laboratories, can talk about Laboratories' accomplishments in only the most general terms at present; but as an interim report, pending war's end, his contribution to this issue will make every System man and woman proud of the ways in which the Laboratories is hastening victory. Dr. Buckley entered the Bell System in 1914 as a research physicist; became assistant director of research of the Laboratories in 1927, and director in 1933; was

John J. Hanselman

Harold S. Osborne

Oliver E. Buckley

Richard C. Smith

Ralph I. Mabbs

Frank H. Lovette

made executive vice president in 1936; and was elected president in 1940. During the previous war he had charge of the U. S. Signal Corps laboratory in Paris, with the rank of Major. He is a fellow of several scientific and engineering societies, and a member of the National Academy of Sciences and the American Philosophical Society. He has recently been appointed to the National Inventors' Council and the Research Board for National Security.

THE ACCOUNT of the construction of the DBR line in this issue is the first to be published concerning this remarkable and interesting project. Even though the big job was completed more than two years ago, mention of it has been restricted until now, for reasons of national security. RICHARD C. SMITH gathered his information through interviews with the men who engineered and built the DBR, and his article represents a cross-section of their personal experiences and observations. Before joining the Pacific Telephone and Telegraph Company as a commercial student in 1924, Mr. Smith served in the Army in the last war, and worked on California newspapers. Since his employment with the company, he has been engaged for the most part in advertising, publicity, and magazine writing. He was appointed supervisor of the news bureau in 1939, and editor of *Pacific Telephone Magazine* in 1944.

WHAT ARE the Bell System's facilities for transmitting FM (frequency modulation) radio programs? And what is frequency modulation, anyway? These two questions are of interest to many people, including telephone people, and the answers to them are the subject-matter of the article which will be found on later pages. So many hands were involved in making light work of a technical subject which may easily be heavy going that the author can be listed only as that well-known and prolific writer, ANONYMOUS.

THERE'S MORE to a long distance circuit than a pole and a wire. To plan the path of a long distance call from the calling to

(*Continued on page 288*)

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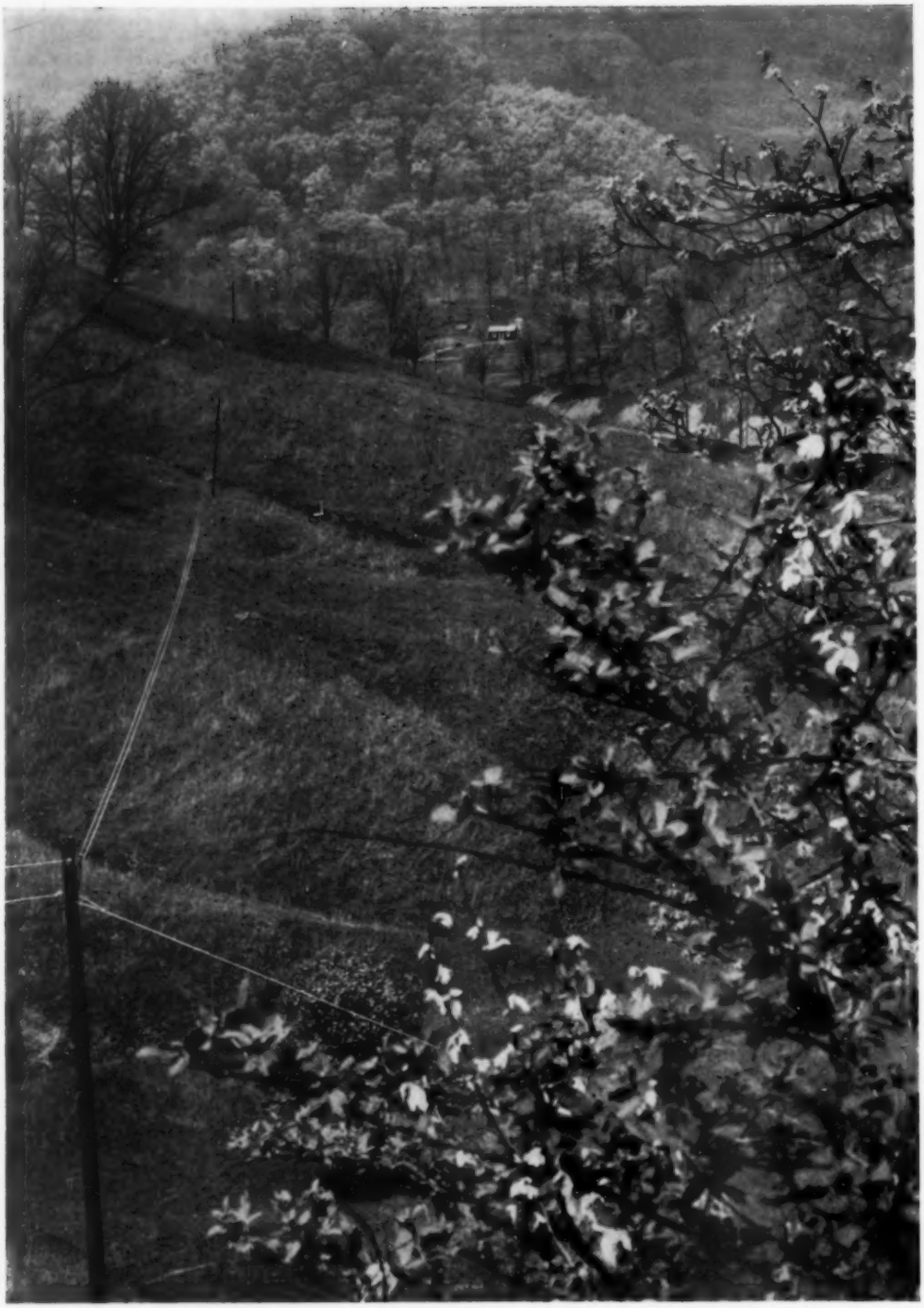


OVER THE HILL on private right of way strides this long-span high-strength steel wire telephone line to the farmhouse in the valley. See the article beginning on the opposite page

The Bell System Plans to Provide Service to Another Million Farms as Quickly as Men and Materials Become Available to Carry Out Its Extensive Program

More and Better Telephone Service for Farmers

John J. Hanselman and Harold S. Osborne

THE BELL SYSTEM has plans for extending telephone service to another million rural homes within three to five years after men and materials are again available. This program, which will cost about $100,000,000, calls for adding as telephone customers half the farms in Bell territory not now having service. When this objective is attained, there will remain for future telephone development in Bell System territory less than one-third of the farms. And the program contemplates continuing and accelerating the modernization of the farmer's telephone equipment and improving the quality of his service.

While this is obviously a tremendous undertaking, it is primarily a continuation and an expansion of a rural program which had been actively under way for a number of years until the war cut down its pace. Since 1940, in the country as a whole, telephone service has been installed on nearly 400,000 additional farms; since the bottom of the depression, in the mid-1930's, the additional farm telephones amount to more than 500,000.

The United States leads the world in telephone development—and this is true not only with respect to telephone development in the larger towns and cities but also in the smaller rural communities.

That is the foundation on which the System's program is built—and from which it marches forward.

The steps by which this far-reaching expansion of rural service will be brought about—and some of them are under way now on a test basis in various parts of the country—are

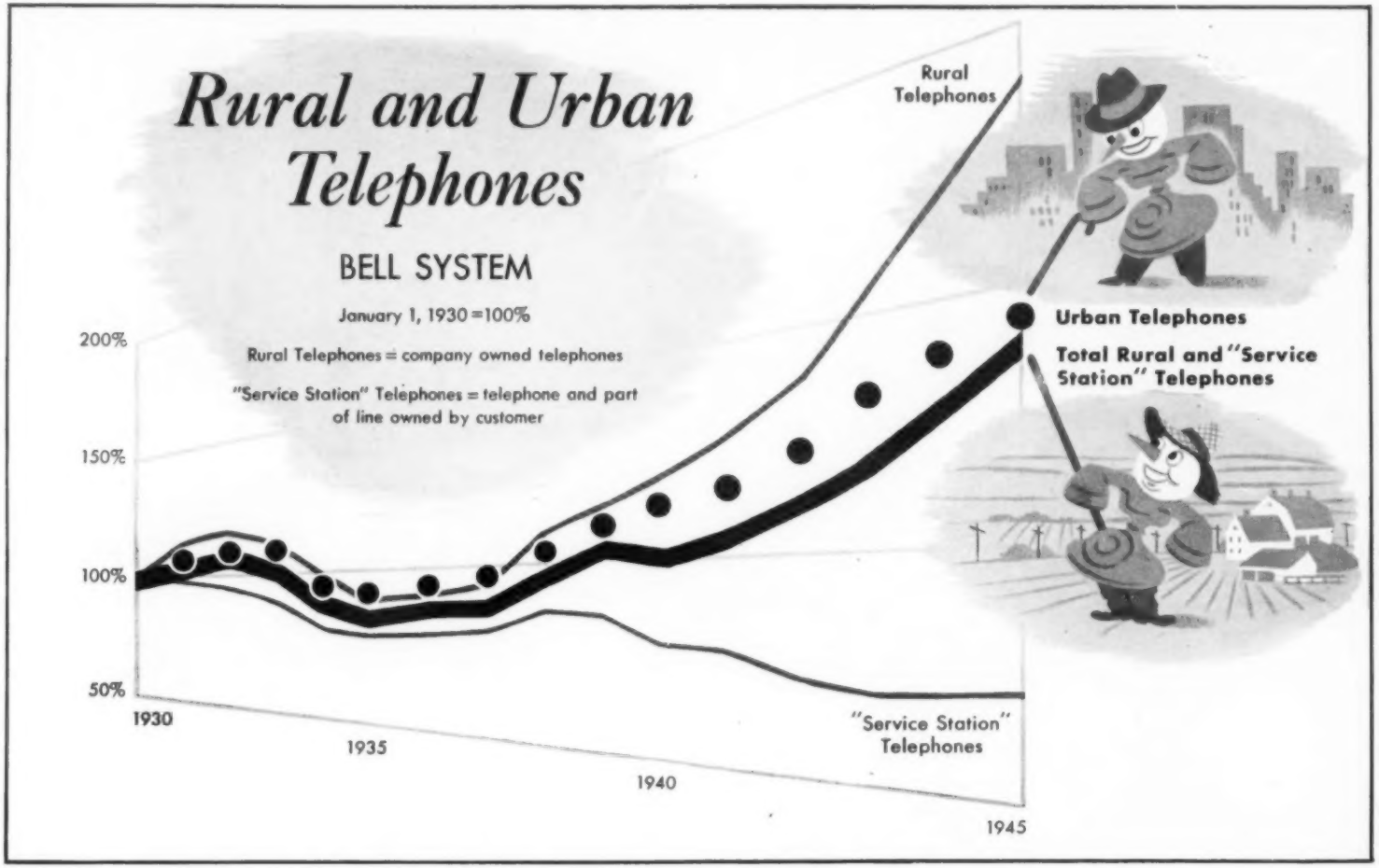


CHART I, showing the substantial growth of telephones in rural areas

already well defined. They include, in brief summation:—

1. Finding out the particular features of telephone service desired by present and potential customers in rural territory;

2. Laying plans for extending facilities to areas not now reached, using latest economical methods of construction;

3. Setting up specific plans for improving service and modernizing facilities; and,

4. As these steps are accomplished, making sure that people without telephone service understand both its availability and its many advantages—in increasing the efficiency and profit of farm operations, in bringing help in time of need, and as a means of keeping in touch with friends and relatives.

MOREOVER, the independent telephone industry is understood to have plans for extending telephone service in farming and "country" areas which in the over-all run parallel to the Bell System program. Speaking by nvitation at the annual meeting of the U. S. Independent Telephone Association last autumn, President Walter S. Gifford of the A. T. & T. Co. said in part:

"The point is that it [rural telephone service] is not developed as far as we in the industry would like to have it. As a post-war objective, I suggest that the entire industry unite on the problem of finding ways and means to furnish satisfactory telephone service for the farmer at a cost that more of them can afford. Fortunately, there are developments in sight that make it look as if this could be done."

Since that time, a committee of experienced operating men has been appointed from among members of the independent telephone industry to attack the problems of rural service on behalf of the Association.

It is thus apparent that the problems—and they are real and many—of extending and bettering service to the country's farms and rural enterprises are being approached by the telephone industry on a broad and realistic basis.

The Economics of Farm Service

THERE ARE many evidences that the proportion of farms with telephones is related to, and indeed is substantially affected by, the economic welfare of the farming and rural population.

In terms of monthly rates, telephone service is one of the least expensive conveniences which farmers can enjoy: the equivalent in outlay, for example, of not more than two or three gallons of gasoline a week and often less. Rates for *rural* service (where the company provides all the facilities as well as the service) have, on the whole, decreased somewhat during the last 15 years. Rates for *service-station* service (for which a mutual association or coöperative group provides the telephone instruments and part of the line) have remained relatively stable at a nominal charge. In connection with this latter service, the telephone company provides the line from the edge of town to the central office, as well as the switching service. The rates for both types of service vary from place to place, of course, in consonance with varying conditions.

The trends in rural, urban, and "service station" telephones during the last 15 years are shown on Chart I on the opposite page.

Company-owned rural telephones

in the Bell System have increased steadily since their low point in the 'thirties and, significantly, at a faster rate than urban telephones.

Service-station telephones, on the other hand, have decreased somewhat. The decrease may not all represent a loss in farm telephone service, however; for there have been numerous instances of farmers who have wanted to be relieved of the responsibility of maintaining a satisfactory grade of service and have asked the Bell company to buy, maintain, and operate the service line as a company-owned rural line. Also, consolidation of farms and farm homes, and other consequences of economic stress, have probably had a part in lessening the number of service-station telephones in use. But despite their decrease in recent years, service-station lines will undoubtedly continue to have an important place in serving much of the remaining territory. This includes the more sparsely settled sections, where a group of farmers find it more economical to build their own pole line; the marginal farm areas, where the low service-station rate is particularly attractive; and also those situations

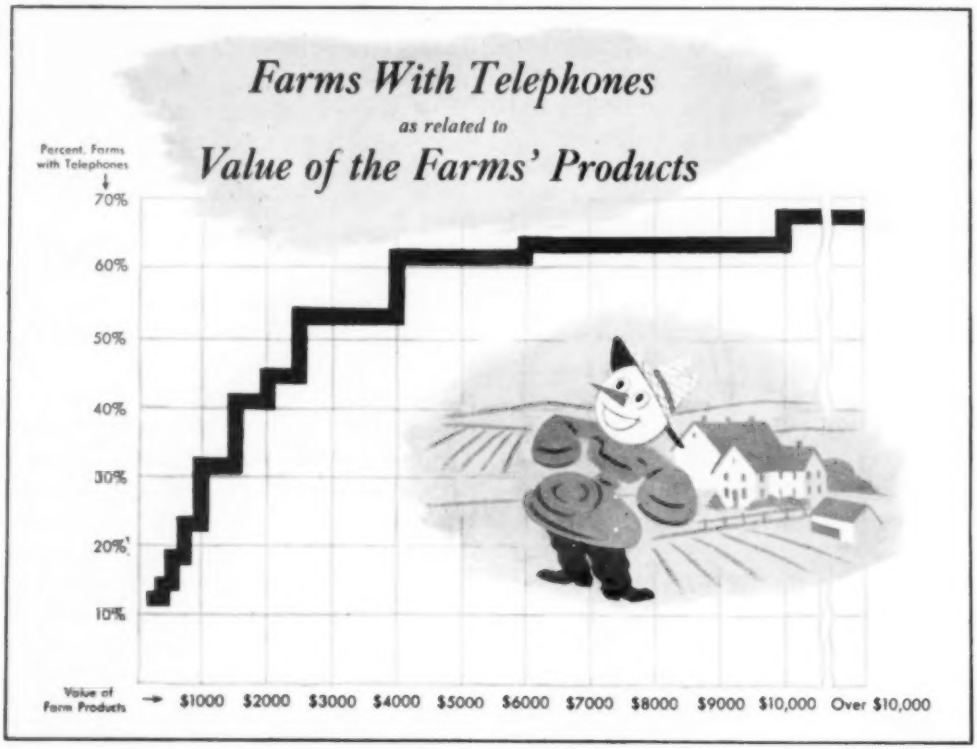


CHART II, illustrating how the proportion of farms with telephones increases with the economic welfare of the farmer

where farmers, because of their other coöperative activities, prefer service from a mutual group or coöperative organization.

Although service-station telephones are fewer, the total of these and company-owned rural telephones combined shows an increase which tops by a substantial margin the previous high point of 1931. It makes an interesting comparison to note that the two combined have increased since the depression at almost as fast a rate as have urban telephones. Herein lies further indication of the continuing attention which has been devoted to the extension of telephone service among the farming population.

THERE IS a considerable variation in the rural telephone development in different parts of the country. Indications are that these differences are primarily due to differences in the economic welfare of the farmer rather than to rate levels or other telephone factors. For example, in two states having for many years about the same levels of telephone rates, the percentage of farms with telephones is more than 40 in one case and about 15 in the other. The average value of farm products per farm in the former state is approximately $1,500, and in the latter it is about $700.

The relationship between farm prosperity and farm telephones is illustrated again by Chart II, which shows how the percentage of farms with telephones increases in proportion to the value of the farms' products. The chart is based on data from the U. S. Census of 1940, which also indicates that nearly one-fifth of the nation's farms have farm products of an annual value of less than $250, and that almost another ten percent, principally in the South, are farmed by share-croppers also having a very low average annual value of products. It can be demonstrated, county by county across the nation, that when and where farmers are receiving reasonably good prices, there the percentage of farms with telephones has been high—and that the converse is also true.

It is evident, therefore, that while the telephone industry feels it can increase substantially the telephone development on farms, the problem has been and is more difficult in areas where the economic status of the farmer is less satisfactory.

Means for Providing Service for More Rural Customers

ALONG WITH its market analyses, and its highway-and-byway surveys of facilities for present and prospective telephone users, the Bell System is searching intensively for means whereby telephone costs as well as telephone lines may be brought within the reach of more rural homes.

Estimates indicate that about two-thirds of all rural homes lie along existing telephone pole lines. Since one-third of all rural families have telephone service, this means that approximately half of the families along existing pole lines now have telephones. It is estimated, moreover, that 80 percent of all rural families are located either along existing pole lines or near enough to them so that service can be carried to them without a special construction charge.

The challenge which the rural problem presents to the nation's telephone industry is, therefore, two-fold. It consists not alone of extending facilities to the 20 percent of farm families not now close to existing telephone pole lines: it includes also the need

A "SERVICE STATION" telephone line using ordinary steel wire, serving a fruit growing region

for making the advantages of telephone service more fully understood by the families within easy reach of lines now in place; and, as an important part of this last, for improving the service furnished to rural telephone users.

Although war needs for men and materials now restrict the extension and betterment of plant, many extensions of rural lines to serve farmers are being made under present WPB regulations, which give preferred status to producers of substantial quantities of food. In building these extensions, advantage is taken of the development of methods for using high-strength steel wire. This permits "long span" construction, with distances of from 350 to 450 feet between poles, instead of the former 150 to 200 feet, and reduces by nearly half the cost of building rural lines. The part which this type of economical construction can play in extending pole lines, after the war, is apparent.

Further economies in the future are also expected through the increased use of mechanical devices such as pole-hole diggers, and through other improvements in construction methods.

PRIOR TO the war, a new type of rubber covered wire for rural telephone service, which could be buried directly in the ground, had been developed by Bell Telephone Laboratories, and with it a plow which, drawn through the earth by a truck, deposits the wire two feet below the surface in a single operation. This wire has already proved itself useful in some kinds of soil, and after the war its use is expected to be extended through improvements in its construction.

Another possibility, of a different sort, lies in the installation of very small dial switching units near groups of farms, giving the farmers and their families more direct communication among each other and reducing the

amount of line wire required to connect them to their telephone exchange. The post-war outlook for increasing the usefulness of this arrangement is already being investigated.

A MOST interesting development, actively under way until war requirements took precedence, is a means for taking telephone service to farms which are remote from existing telephone pole lines but are situated along electric power lines. This development is known as "power-line carrier," and involves using electric power wires simultaneously for power service and for telephone service. It applies to this use a technique perfected over many years by the Bell System to make possible the transmission of many telephone conversations over the same pair of conductors simultaneously without interference. This is accomplished by the use of high-frequency currents which are commonly said to "carry" the telephone conversation.

As applied to "power-line carrier," this means, in non-technical terms, that a high-frequency telephone current, carrying conversation, can "hitch-hike" a ride along an electric power line, hop off the power line at an appointed spot and onto a pair of telephone wires running into the customer's premises, and thus reach the telephone, over which conversation takes place in no way different—to the speaker—from normal telephone usage.

Electronic apparatus which creates the high-frequency current and, when a person is speaking into the telephone, varies or "modulates" it in such a way that it can carry the conversation, is installed in or near the central office and on the customer's premises. The high-frequency telephone currents hop on and off the power line by means of "carrier couplers" installed on the power-line pole. These couplers do not permit the power current to pass; but the telephone carrier currents, being of very high frequencies, can pass over the power line simultaneously with the power currents, without any mutual interference, whereas this could not be done if ordinary telephone currents were used.

SPANS averaging from 350 to 450 feet, using high-strength steel wire, materially reduce construction costs

SUCH A PLOW, pulled by a truck, buries rubber-insulated telephone wire in the ground in a single economical operation

To accomplish all this, the equipment at the subscriber's premises will probably appear like a small table-model radio, including vacuum tubes, and with it will be associated a telephone. It must be provided with power from an ordinary electric outlet and must be energized continuously so that it will be able to receive telephone calls at all times. The apparatus at the central-office end will be similar but slightly more complicated. The layout of a power line carrier system is illustrated on pages 222 and 223.

To the operator at the switchboard, a power-line carrier circuit will appear no different from a wire circuit. Power-line carriers will give the same types of service as the present wire circuits. The subscriber will receive rings in the same way as over wire circuits, and will make calls to the operator in the same way as subscribers on common-battery wire lines, simply by lifting the telephone from its cradle.

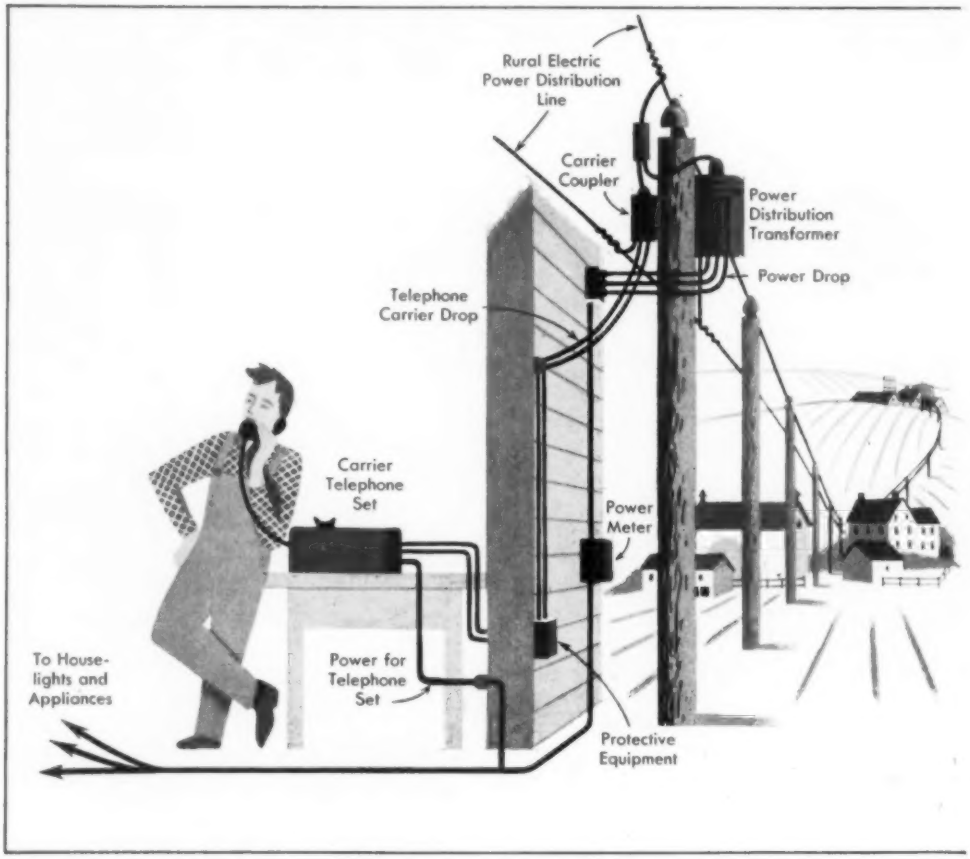
While power-line carrier development is not completed, present indications are that it will be useful in extending telephone service to many of the 20 percent of the farms in Bell territory which are not near existing telephone lines.

Bell Telephone Laboratories and the System companies are coöperating with both the Rural Electrification Administration and private power companies in working out the application of this system. As soon as war conditions permit, the Laboratories will complete its development and

make it available for use by telephone companies and by service-station organizations to help extend service to more farms.

While the use of carrier-current systems to increase the number of conversations which can be carried by telephone wires on a pole line has long been an important feature of long distance telephone service, it has not heretofore been possible to design such systems for economical use on rural telephone lines to increase the capacity of the wires in place of stringing more wires on the pole line. It is hoped that, after the war, new developments will make this possible, and that carrier can be used on rural telephone lines as well as on rural power lines, both being to the benefit of farmers and farm service. Of course a major distinction to be made between these two uses is that carrier on rural telephone lines simply provides, in general, more circuits along established pole-line

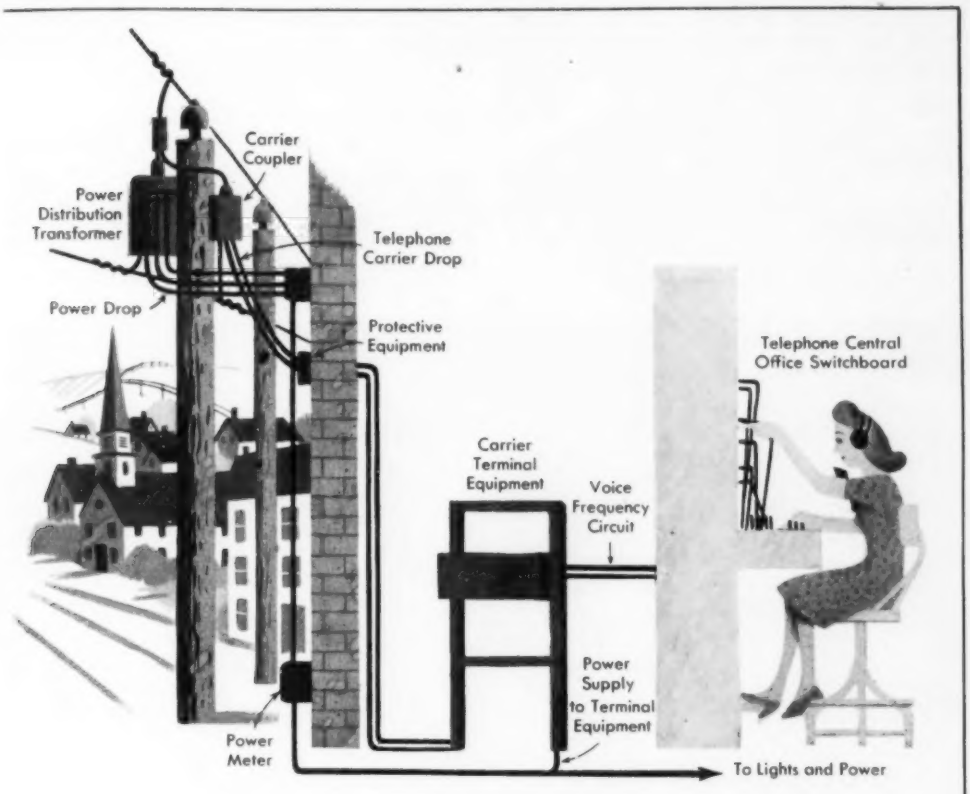
A POLE HOLE DIGGER makes quick work of line construction where ground conditions are favorable. A lighter machine is being developed for rural construction



A VISUALIZATION of the principal physical features of the "power

routes, whereas carrier on rural power lines may avoid the necessity of building or extending telephone pole lines.

THE TRULY remarkable accomplishments of radio telephony in the war have brought many suggestions for—and some fanciful pictures of—the peace-time use of this means of communication, particularly as an aid to farmers and others in isolated places. The Bell System has had a good deal of experience as to the place of radio in telephone communication, and will undertake further studies of its use for rural service as soon as the war ends. It has already requested the Federal Communications Commission to make available 40 frequency assignments for 20 rural customer circuits with which to conduct experiments and develop this type of service. These frequency assignments would be suitable to be duplicated over and over in different localities. Short-wave frequencies of the type contemplated have limited transmission ranges, usually not extending



line carrier" system designed to help in serving rural areas

further than the limit of vision, and it now seems likely that radio telephony for rural service may find its principal field in providing extensions of telephone service to farms so remotely situated as to be beyond the reach of even extended telephone pole lines or of power-line carrier.

These new methods of construction and new types of facilities form a powerful array for extending the scope of rural telephone service so that it should be possible to reach, on a reasonable basis, practically any farmer desiring telephone service for himself and his family.

Improvements in Service

THE BELL SYSTEM COMPANIES propose not only to make telephone service more readily available to all parts of the rural areas which they serve, but also to continue their program of making the service better and, as a consequence, more desirable. Originally, most rural telephones used the "magneto" type of system,

in which the subscriber must turn a crank to signal the operator. About three-fourths of the System's rural telephones now have the type of signaling used in cities, where the central office is signaled simply by lifting the telephone from its cradle. The companies propose to extend this form of service systematically, for the most part replacing the old form of magneto service with dial service and for the rest making available common-battery manual service.

A TELEPHONE MAN shows a group of interested farmers how to make a twisted-sleeve splice in their service-station line

For years, most rural customers were summoned to the telephone by what is known as code ringing. In this system, ringing on the line by an operator is heard by all subscribers connected to that line, and a code is used to indicate which subscriber is to answer. Now well over half of these telephones have some form of selective signaling, whereby the rings of only a part of the people on the line are heard by any one subscriber. It is hoped after the war to extend this use of selective ringing to substantially all rural customers.

The clearness of transmission on rural lines will continue to be improved. Much has already been done by changing grounded circuits to metallic circuits. The latest and most efficient types of telephone

transmitters and receivers have been introduced in rural as well as in urban service as they have become available, and it is estimated that 60 percent of rural telephones are already equipped with them. This proportion will be rapidly increased after the war. Also, the number of subscribers per line, which because of war-time limitations has in some cases become greater than seems desirable for normal times, will be reduced.

The greatest increases in value of service come from these improvements in the quality of service and from increasing the number of people in a community who have telephone service. In addition, a number of System companies plan to make experiments in the further extension of information features, such as weather forecasts, bus schedules, and other items of direct concern to farm customers.

An important part of the service in rural areas is given by the mutual service-station groups already referred to. The Bell System has long recognized their importance in making nation-wide telephone service a reality, and the operating companies have made a point of assisting them in many ways—particularly since the depression. The companies have organized groups of experienced men whose function is to help these service-station groups. As the man-power situation eases after the war, even more of this will be done. Such assistance is broad in scope, ranging from advice on how a group should organize for service and build the line, to continuing assistance in connection with its maintenance.

Obtaining Basic Information

SO GREAT an undertaking as the Bell System's rural service program must build on a sound basis of fact and information, and inquiries and surveys are fundamental to it. Some of these are already under way, and will be expanded as, again, peace brings the men and the time to do so.

A new tool used in the Bell System to make an improved wire joint

Even now, a good start has been made on determining what people in rural areas think about telephone service: what they like and don't like about it; what they feel it should include; what improvements and new features would make it more pleasing

and useful to them. It may surprise some readers to learn, for example, that in one area more than half of the rural customers interviewed during these local surveys said that they did not object to "listening in" by others on the same line. When enough information has been compiled, from various sections of the country, it will be analyzed, and will serve as a guide in developing those aspects of the System program.

AS A HELP in making final plans, detailed surveys will be made of many typical areas in various parts of the country. These surveys will be made by teams of men, from several departments of the telephone companies, who will drive up one road and down the next until a given section has been thoroughly covered, making careful notes as they go along. They will gather facts on such points as farm and non-farm establishments, present and potential telephone customers, whether telephone or electric power line passes the premises, present condition of the line, sections requiring pole-line construction, soil conditions, and other pertinent data. All this information will serve as a basis for engineering plans to provide satisfactory telephone service to present and new customers in the most economical way.

When an aggressive program of improvement and extension of service again becomes possible, telephone company representatives will go out to interview farmers and others who do not have telephone service; for the System's obligation, as the telephone companies conceive it, is not fully discharged simply by making the service available to as many people as possible. It is met only when, in addition, those who do not have service understand the basis on which they can have it, and appreciate its value in neighborliness, in emergencies, and in their business—for farming is a business. The telephone representatives' efforts will be supplemented by advertising through such means as farm journals and rural newspapers and at county fairs and other gathering places.

THE PLANS are well along. Progress is being made now in advancing the program as fast as possible under war-time conditions. When materials and manpower become generally available, the farmer will reap full benefit of this program for extending and improving his telephone service.

The end of the war, moreover, will bring back the System's people now in the services—some 60,000 of them. The $100,000,000 rural program, with its objective of a million more rural telephones, will be an important factor in providing work for a considerable number of these telephone soldiers and sailors.

War Contributions Emanating from the System's Research and Development Organization Are Demonstrating the Value of Its Peace-time Methods and Ideals

Bell Laboratories in the War

Oliver E. Buckley

WORLD WAR II is generally recognized as exceeding all previous wars in the demands it has laid upon science. There is scarcely any branch of learning which has not made important military contributions. Physics, chemistry, and mathematics have perhaps held the foremost place among the sciences in inspiring a procession of new weapons and new techniques. However, there is scarcely a department of science which has not rendered its indispensable, if less obvious, service.

Although everyone concedes the many war-time contributions which scientists and their specialized knowledge are making it is safe to say that not one person in a hundred understands the tremendous expenditure of time, money, and effort necessarily entailed in the actual process of focusing the nation's scientific acumen on military problems. All too often science is regarded as wizardy brought up to date, and so effective that brilliant discoveries and inventions can in weeks, if not in days, be translated into new weapons for the battlefield. The facts are quite otherwise, however. In reality, science usually provides only the foundation of knowledge on which inventors and designers systematically and patiently build. Much time and great engineering skill are required to convert the new ideas and designs into serviceable military tools. A successful laboratory demonstration or even a field trial of carefully conceived design almost invariably marks but the beginning of a long succession of testing and modifying, to be followed by more testing and more modifying. Months of hard work, much skill and, frequently, inspiration born of perspiration are the unseen ingredients of every successful new instrument of war.

In this regard there is little that is unique about reduction to practice in war-time. It is much like reduction to practice in peace-time, although under the stress of hostilities the urge for rapid completion of projects is naturally keener. The skills and techniques of pre-war industrial research have therefore been an invaluable war asset of the nation. When beset with a sudden demand to encompass in their arsenals as much of present-day science as possible, as well as to devise the most successful countermeasures to the enemy's ingenuity, the armed Services naturally looked to the laboratories of applied science as one of their chief sources of help. In these institutions they have found groups of workers whose profession it is to adapt science to practical ends and who have acquired great facility at it.

As the largest organization of this kind in the world, Bell Telephone Laboratories has been able to render outstanding assistance to the armed forces of the United States and of our Allies. The part it has played has been a source of pride to all of us who are its members. With scarcely an exception, everyone has had a chance to contribute directly to the war effort. Indeed, from what military authorities have told us, it is evident that the war would have been longer and its consequences more serious had the Services lacked the technical tools that have been devised and perfected within our walls.

To tell the full story of the war activities of Bell Telephone Laboratories would be impossible within the limits of an article of reasonable length or even a book of reasonable size if justice were to be done to the 1,200 or more projects on which major contributions have been made. One measure of its magnitude is its cost—well over $100,000,000—but that appears a poor measure indeed when one observes the variety and complexity of technical work which it covers and the military importance of the products which have emerged.

Even if it were practicable, considerations of secrecy suggest that the full story of our war work may never be told. As it can be released and as the time of those doing the work becomes available to tell about it, the more interesting parts will be described in appropriate technical articles. It is now possible, however, to give a general outline of our war activities, to indicate their character and distribution, and to explain the policies and methods of operation which have been employed in this most interesting and significant chapter of the history of Bell Telephone Laboratories. These policies and methods are not new, but are the natural outgrowth of our long-established methods of operation as a unit of the Bell System.

A Unique Organization

BELL TELEPHONE LABORATORIES is in many ways a unique organization. It is not only the largest research and development organization but it probably covers a wider range of activity than any other similar group, even though in its normal activities its attention is focused on the single field of electrical communication. In that field it covers the full gamut of technical matters relating to the telephone, both wire and radio, starting with the very fundamentals of speech and hearing and the physics and chem-

istry of the various elements that make up the complex telephone plant. It combines knowledge gained from fundamental research with intimate knowledge of performance requirements in the design of instruments, apparatus, and equipment which it develops to the point where they are ready for production. It also tests out new products under actual conditions of use, prepares information for maintenance and operation, and continues to make studies of behavior of these products throughout their subsequent life.

THE MURRAY HILL buildings of Bell Telephone Laboratories, designed to accommodate about 900 people, under pressure of war work now house 1,200. They include many novel structural features which adapt them to laboratory needs and make them perhaps the most outstanding buildings in the country for scientific research

In this work we as members of Bell Telephone Laboratories have only one objective: to make certain that the equipment that we devise and design will be such as will achieve the end of the best possible telephone service at the least possible cost. This is a very different objective from making things to sell in a competitive market. It calls for study from the users' point of view and takes into account the cost of maintenance and the value of continuity of service quite as much as first costs. In this process, too, we consider a piece of telephone equipment not as an item to be appraised by itself but as an operating unit of the system of which it is to be a part. From the very nature of telephony, it is essential that the parts of the system fit together and be engineered to that end to a degree required in few other fields. Consequently, "systems engineering" has played a dominant part in every aspect of Bell Laboratories' work.

Another feature that distinguishes the methods of Bell Telephone Laboratories is its close association on one hand with the Western Electric Company as manufacturers, and on the other hand with the Operating Companies of the Bell System. These as-

sociations make possible intelligent engineering of equipment for economical production as well as engineering for reliable service as part of an intricate system.

It is readily apparent that these methods, which have proved highly effective in relation to the Bell System, are equally adapted to the technical problems of producing tools of war designed to serve military needs. Add to this the fact that communication has played an extraordinary part in this war of rapid movement, and the even more significant fact that the techniques of communication have brought about revolutionary changes in many other military fields, and it is not surprising that we were in a position to make vital contributions to the effective prosecution of the war.

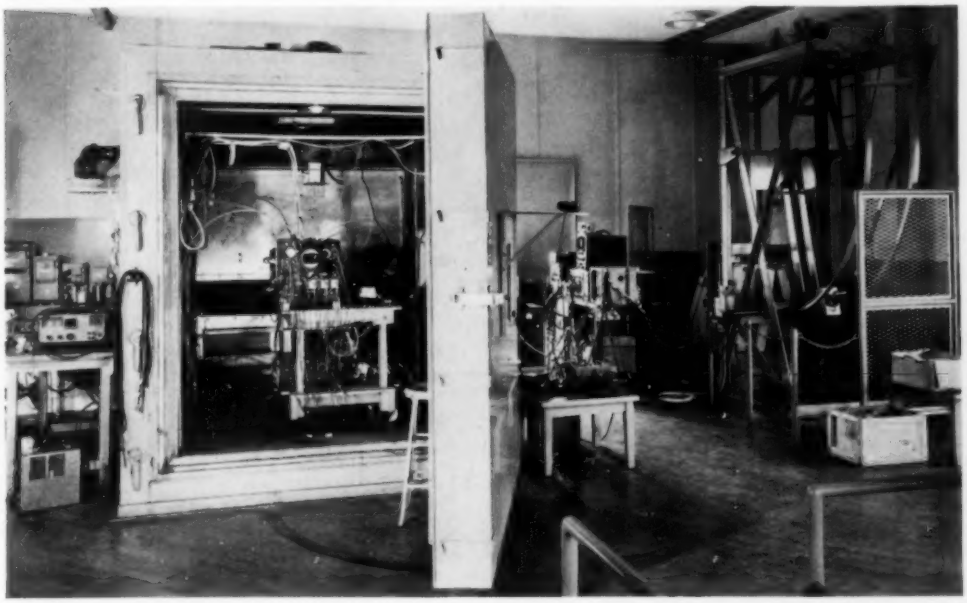
Actually, our entry into war work was gradual. Ever since World War I, we had maintained a department for serving agencies outside the telephone system in special applications of the techniques of telephony. A part of this work was in the field of radio communication for the military Services. As the Services began preparations for a possible conflict, their demands on us especially for radio grew, until by the time of Pearl Harbor 30 per cent of the entire activity of the Laboratories was on behalf of government war agencies.

A PEACE-TIME SCENE in one of the laboratories of the Switching Development department. The flight crew trainer was created in this department. The department's normal activities include the development of dial and manual central office switching systems for both local and toll service, and allied signaling problems

With the country's entry into the war, this effort expanded rapidly, until our efforts were soon almost wholly devoted to those problems where it seemed we could best play our part in the national effort.

We have contributed major developments in such diverse fields as communication systems and equipment, radar systems and equipment, devices for undersea warfare, and electrical gun directors; we have contributed new materials, devices, and techniques which have found important applications in fields far removed from our normal lines of activity. We have also engaged extensively in the manufacture of pre-production equipments, and have operated a large school for the training of Army and Navy personnel.

Although our first work connected with the war was in fact a continuation of military communication work carried on for many years previous, we had, prior to the war, engaged in other fields of war interest bordering on communication. Most notably was this so in radar development, which eventually became our greatest war activity. We started this line of work in 1937, in coöperation with the Navy, and by the time of Pearl Harbor had already made many significant contributions to this new art. In our communication experience we had



A CORNER of a Life Test department at Whippany, New Jersey. Models of military equipment developed and engineered in the Laboratories are always subjected to rigorous tests involving extremes of temperature and humidity. In the large chest at the left refrigeration tests are made, the equipment under study being operated and observed by means of the electrical connections seen hanging from it

a preparation for this line of development unequaled by any other laboratory. In many other fields, too, we found that the special skills and techniques which had been developed to meet telephone problems could be applied to new problems brought on by the war.

Developments in Wire Systems

IN THE FIELD of wire communication, much of our war effort has related to the adaptation of existing arts to the needs of the Army and Navy. Portable equipments, specially packaged for use in the field, were built of standard parts using standard or near-standard circuits and methods. New kinds of wire and cable and new types of construction to meet the needs of modern warfare had to be developed. A great variety of new telephone instruments to permit talking in tanks, airplanes, and for use with gas masks were devised. A new multiple horn loudspeaker system, used extensively in both land and naval operations, is worthy of special note. Another very important contribution is the portable information center for the control of air operations; with it, all information is brought together at one point for directing the course of an aerial combat.

In a rapidly changing forward area, a backbone of wire communications which can be installed very quickly is a vital requirement of the Ground Forces. The system developed to meet this need employs the spiral-4 cable. This cable comprises four rubber-insulated wires symmetrically laid up to provide two balanced circuits, lightly loaded with loading coils inserted at the terminals of quarter-mile sections. On these circuits three telephone and five telegraph channels are normally provided.

Developments in Radio

RADIO COMMUNICATION, from the development point of view, has weighed more heavily than wire communication because of the highly mobile character of the war and the less mature state of the radio art. In this field our principal activities have been in radio for airplanes, tanks, and mobile artillery, in overseas radio circuits, and in broad studies of radio communication systems. Airplane radio telephony has been a subject of continuous development in Bell Laboratories from its inception in our Laboratories during World War I. Although our armed Services were well prepared in this regard before going into the war, new conditions called for changes which could not have been foreseen, and modification of radio equipments had to be made to meet them.

The tremendous demands for radio communication among all kinds of moving vehicles of warfare called for great precision and great facility in the selection of radio frequencies. Quartz crystal control proved the key to this problem, and crystal-controlled sets were developed for tanks and other vehicles. Some sets use as many as 120 crystals, each adjusted to a high precision. The development of methods of cutting and grinding crystals with minimum waste of raw material became a major activity. Indeed, the supply of quartz became one of the major supply problems of the war and would have been critical except for the closest coöperation between the Signal Corps, the Western

Electric Company, and our Laboratories in the development of methods to economize its use. Through the Signal Corps these methods were made available also to other manufacturers and are now applied on a wide scale.

use of some of the equipments and methods developed in the Laboratories in the pre-war era for overseas telephony. By applying carrier telegraph techniques to short-wave telephone circuits, a degree of reliability of telegraph operation was secured

SIGNAL CORPS maintenance men are shown as they set up spiral-4 cable and messenger for Seventh Army communications. Many will recognize the characteristic French telephone line construction in the background

The overseas radio network of the armed Services is one of the most remarkable communication achievements of the war. It reaches to all corners of the globe and provides for a greater volume of communication than all of the pre-war radio and cable systems combined. The overseas radio links of this system make that greatly surpassed the previous overseas radio telegraph art.

Shorter range point-to-point radio systems using ultra-short waves were also provided to both the Army and Navy. The basic elements for these military systems were drawn from our pre-war development of point-to-point radio for the Bell System, and,

particularly, from the radio link from Cape Cod across Massachusetts Bay and the link connecting islands in Chesapeake Bay with the mainland, each of which has been in use for several years.

So vital have extended radio facilities been to the American forces, that a study of radio systems as distinguished from radio sets became an early necessity. Emphasis on the performance of radio equipments as single units rather than parts of a communication system involving antennas, transmission paths, interference, and other factors extraneous to the radio set, was characteristic of much pre-war radio development outside of the Bell System. This situation led first to our being requested to undertake a study of radio communication systems to meet the needs of the Army Air Force; later this grew into a broader study of Army communication systems generally. The products of these studies have proved of great military value.

The Laboratories and Radar

THE DEVELOPMENT and pre-production of radar systems and equipment have, from the start, represented a large part of the war activities of the Laboratories. Radar components and testing equipments of the Laboratories have been used extensively in systems designed by others. Our outstanding position in this field is an outgrowth of our pre-war development of communication systems involving techniques and methods of measurement later applied to radar. Experience in the art of measurement made it possible, in turn, for us to progress rapidly in the development of various components essential to the success of radar techniques. These collateral lines of investigation have proved valuable not only for our own progress in the radar field, but for that of other radar development agencies in this country and England, to all of whom they have been made freely available.

Close coöperation with agencies of the National Defense Research Committee has occurred in this and other fields of development. Through this means, the research skills of many of the outstanding academic scientists of the country were combined with those of industrial scientists and engineers to meet in a most remarkable way the technical problems brought on by the war.

Underwater Sound

DEVICES for undersea warfare represent an important area of our war development effort and one of close coöperation with the National Defense Research Committee. Included are not only instrumentalities for detecting and protecting against enemy submarines and mines but also devices useful in protecting our own submarines. In this field, too, an important contribution has been our development of techniques and instruments for precision measurement.

One of the most important elements of undersea warfare is underwater sound, since radio is ruled out by the conductivity of sea water. At the beginning of our attack on problems of underwater sound, we undertook to develop methods of measurement. Automatic means for measuring the performance of underwater generators and receivers of sound were developed to the point that in the course of a few minutes the re-

sponse of a device could be determined with a high degree of accuracy continuously over a frequency range from 50 cycles to 100 kilocycles. Devices for producing and detecting underwater sounds had previously been designed largely by cut-and-try methods and without the benefit of quantitative knowledge of their performance. We supplied the means to design on the basis of precise knowledge. Proceeding in this manner, we developed new types of underwater sound instruments that have proved very valuable in the war. Included among them is echo-ranging equipment which represents a great advance over the preceding art. Again our measuring techniques were made available to other development organizations with consequent benefits to their producers.

FIELD ARTILLERY RADIO SETS, such as the one installed in this command car, link forward observers with rifle and howitzer batteries in the rear. Similar sets are used for communication between tanks

The development of the electrical gun director comprises another important segment of our war program. This is a situation in which we proposed an electrical solution of a task which was being performed by a mechanical device. This solution makes use of electronic tubes and circuits

and of other components developed originally for communication purposes, and its success is now fully proved by its having been adopted as standard equipment in both British and American Armies. It played an important role at the Anzio beachhead, again in Normandy, and its latest triumph has been the part it has played in shooting down robot bombs in England. It has gained distinction for its reliability as well as its performance, and we take particular pride in the fact that it was wholly a Bell Laboratories product.

Other Developments

AMONG the miscellaneous developments that do not fall into any of the categories discussed above are items as diverse as airplane crew trainers, improvements in rockets, a shell velocity meter, means of increasing the wear resistance of gun barrels, gun silencers, computing machines, and numerous other items that appear to have little connection with communication. They do, however, have one thing in common, which is that they make use of techniques, methods, or skills developed specifically to solve problems of the communication industry.

A particular case in point is the airplane trainer developed for the Navy to train crews for flying operations. With this device, an air crew is enabled to "fly" a stationary replica of an airplane fuselage completely equipped with its regular quota of instruments and controls while an instructor sitting at an adjacent desk supplies the conditions to which the "plane" is subject in its "flight." Lacking only the mechanical motion of a real airplane, it presents to students conditions which might lead to disaster if they were met in real flight. This trainer has proved outstandingly successful, and models for three different types of airplanes have been developed to date. Such a machine involves as a principal feature electrical computing mechanisms giving the results of variations in a large number of independent and interdependent physical quantities. In this regard its development called for the same kind of approach and required the same skills as does the development of complicated automatic central office equipment. Use, also, is made of many standard telephone parts in its construction.

Development of special materials and studies of properties of materials have always been an important part of Bell Laboratories' activity on behalf of the Bell System. All of our specialized knowledge of materials accumulated over years of telephone development was made available to our armed Services and to manufacturers supplying them. Some of the principal items in this class are magnetic alloys, mica, rubber, natural and synthetic crystals, ceramics of special electrical properties, coatings to protect against corrosion and against fungus and other destructive organisms. In the case of mica, which was a critical material, means were developed to test and sort mica that enabled utilization of grades of mica which had formerly been rejected as unfit for use. In the case of rubber, one of our chemists was called on to lead the fundamental research program of the Rubber Administration, and means were developed in the Laboratories for measuring the degree of polymerization of synthetic

rubbers. In electrical ceramics, advances were made far beyond anything previously achieved, and as with other improved materials of our development the benefits appeared in others' products as well as our own.

EXCEPT FOR certain parts of the work on war projects which promise to have post-war telephone application, our war projects have been handled on contracts made by the Western Electric Company with the government agencies involved. About 55 per cent of such contract work is for the Army, about 35 per cent for the Navy, and about 10 per cent for the Office of Scientific Research and Development.

Our attitude on Army and Navy orders has been to give the Services what they ask for, endeavoring wholeheartedly to meet their performance requirements while making available to them opinions based on our own experience. We have engineered to our usual high standards just as far as considerations of time would permit, subject of course to our limited knowledge of conditions which must be met. As the Services began to bring back knowledge of actual combat conditions from fields of action, our engineers have taken this information into account, with consequent improvements in the quality and the utility of the products. Our equipment has given excellent service in the field and has reflected in the most significant way the benefit of our long-standing policy of engineering for service.

THE *Elcobel* is one of two yachts used by the Laboratories for under-water testing. Their availability greatly expedites the trial, under actual seagoing conditions, of devices and modifications as they originate in the Laboratories

Ordinarily, the activities of Bell Telephone Laboratories are confined to research and development, including the current engineering essential to our broad development responsibility. The products of our devel-

opment are manufactured by the Western Electric Company, the manufacturing unit of the Bell System. At the request of that company and to shorten the time between the first model and quantity production, the Laboratories has undertaken to manufacture small quantities of pre-production war equipment. This manufacture of pre-production equipments, usually in quantities of 25 or 50, has grown until it is a sizeable business, running to well over $1,000,000 a month. In this production, as in shop work on our experimental models, we have, so far as possible, arranged to have parts and sub-assemblies made by outside shops, and have thus sub-contracted work to no less than 200 manufacturers.

PRE-PRODUCTION manufacturing in the Laboratories has expedited the availability of a small number of advance units for early training in maintenance and operation, a matter of great advantage to the Army and Navy. It has also expedited quantity production by giving the engineers of the Western Electric Company an opportunity to base their manufacturing planning on observation of the equipment under manufacture in the Laboratories.

In a number of instances the amount of equipment required by the Services has been so large that part of the manufacturing has been placed with other companies through subcontracts by Western Electric Company. Some of these companies later became prime contractors for the equipments upon which they first operated as Western sub-contractors. Thus a number of manufacturers outside the Bell System are now building equipment to specifications developed in the Bell Laboratories.

The School for War Training

THE LABORATORIES has also taken a direct part in the Army and Navy training program through the Bell Laboratories School for War Training. Nearly 4,000 students have been instructed there in the utilization and maintenance of new special equipments in radar, fire control, underwater sound, and radio communication. So successful has this training been that the Navy now requires each combat vessel to have on board at least one officer graduate of our Laboratories School.

In conjunction with this school work we have prepared many of the instruction books for use with the equipments we have developed. A complicated piece of military equipment is of little use without a set of instructions. The preparation of such material has been a stupendous task, no less than 650 books having been written, many of them large volumes. Indeed, from the standpoint of number of new books published, the activities of Bell Laboratories exceed those of the largest private book publishing concerns.

IN ADDITION to the work done within the Laboratories, many of our outstanding scientists and engineers have served on government committees, including particularly various subcommittees of the National Defense Research Committee. More than 30 have been so engaged extensively and some have been loaned for full-time service while many others have served in limited capacities. We were governed in this by the desire to make

the most effective use of each individual's time in the national war effort.

Many demands have also been made on us for the transfer of skilled personnel to the Services or to the National Defense Research Committee. We have not always been able to meet these demands, for had we met all of them we would have had little technical staff left and it would not have been in the interest of the war effort that we do so. We have, however, transferred more than 100 professional employees to the Services and a small number to the National Defense Research Committee or its academic sub-contractors. In many instances, this loan of personnel to the Services, particularly where of limited duration, has been very helpful in our own work. The men who have come back from fields of action have put into our developments the

SHOWN HERE is a portion of an AA battery. In the foreground is the tracker unit of an electrical gun director. This feeds information concerning the position, speed, and course of hostile planes to the electrical computer. Through a suitable nerve mechanism the computer in turn aims the guns visible in the background, giving them the proper lead. As the planes move, the guns move too, being provided with a continuous "bead" by the electrical computer. In carrying out its instantaneous calculation, the computer takes account of all important factors, such as wind velocity, latitude, barometric pressure, and type of propelling powder

benefit of their intimate knowledge of conditions of use.

On top of all the war activities described above, the current needs of the Bell System have also been provided for. In fact, the war has induced many emergency telephone problems. Available materials had to be substituted for scarce ones in equipment being manufactured for regular telephone uses, and this called for much work in testing substitutes and changing specifications. The combined load of war developments and the war needs of the Bell System forced us early in the war to forego almost completely all of our normal lines of forward-looking research, so that we have continued to carry on only that telephone work which was essential to the efficient operation of the telephone system.

To meet the demands of the war program, it has been necessary steadily to expand our forces. We have grown from a group of 4,600 at the beginning of 1941 to about 8,000. Actually, the Laboratories is effectively somewhat larger, for, through outside shops and other work done on contract, we make direct use of the services of about 800 additional people.

While we have carefully controlled the growth of the technical staff so as to maintain its high quality, we have not hesitated to give its members all possible aid by providing assistants, draftsmen, and mechanics to speed the embodiment of the products of their imagination. It is the increase in this assistant technical staff, and in the clerical staff needed to keep pace with the growth in work, that has been principally responsible for our net increase in numbers during the war period.

However, the growth of the staff is by no means a proportionate measure of the increased output, for all have worked under abnormal pressure and for longer hours. Our normal working time of 35 hours a week for professional and office people has been increased to 48 hours and upward for all actively engaged on war work. Many have worked for periods far beyond those scheduled hours, and in some cases up to 80 or even 90 hours a week when it was evident that important war results depended directly on the speed of their immediate accomplishment.

It is a characteristic of the normal method of working in Bell Telephone Laboratories that responsibility is assumed at all levels of the organization. Our people are accustomed to direct action across organization lines. Our method, too, is outstandingly one of teamwork. Most of our problems in normal times call for a variety of skills and knowledge that cannot be the product of any one line of training, and direct contacts are made to bring together the specialized abilities that are needed. This procedure over the years has engendered a spirit of coöperative endeavor that is remarkable in so large an organization. That spirit, in a group predominantly made up of experienced personnel of outstanding quality and specialized skills, has made possible an output of new technical tools of war far beyond what any of us could have predicted. More than that, we now know that it has contributed materially to victory, thus definitely shortening the war.

As a Safeguard in case of Enemy Attack, an Alternative Telephone Line Was Constructed East of the Pacific Coast Ranges in Record-breaking Time

Building the West's New Telephone Route

Richard C. Smith

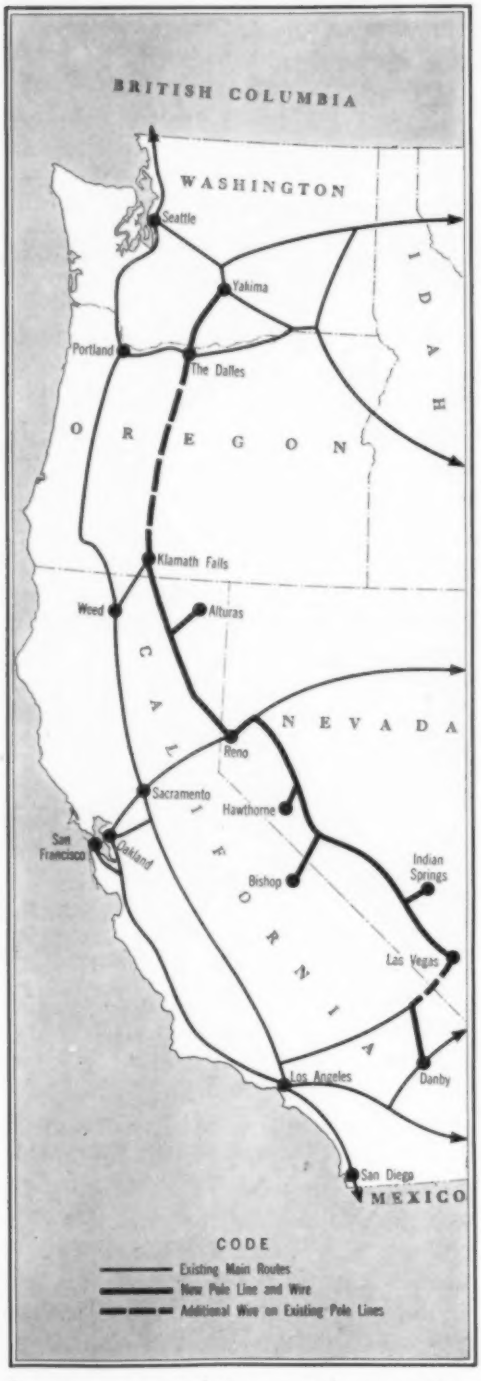
ONE OF THE most outstanding construction projects in Bell System history was completed in the Far West, in 1942, when a new 892-mile long distance pole line, wire stringing on a total of 1,317 miles of line, and the necessary repeater stations and equipment were engineered and completed in one-fourth the time which would ordinarily be required.

Stretching from central Washington to southern California, through mountains and desert which never before had echoed to the clatter of a construction outfit, the line represents a job in which telephone people everywhere can take a lot of pride.

"DBR" is the name by which this unusual line is known—the initials being associated, by those who were in on the job, with the phrase *Damned Big Rush*. Other names often used during construction days were *North-South Toll Lead* and the *Jackrabbit*; the latter for the speed with which it lit out across the country.

The line was built to provide a complete alternative telephone route paralleling the Coast east of the Sierra Nevada and Cascade ranges. Thus protected by mountain ramparts, the wires are relatively safe from enemy attack. The DBR job thus had a close connection with the war effort, and was carried out, as such, with "precision and dispatch."

Engineers and construction men of the Pacific Telephone and Telegraph Company got first wind of the proposed line about April 1, 1942. The project caught the telephone forces on the Coast with a good deal of work already on hand; far too much to take care of a mammoth task of this nature through the regular channels of organization. A new division construction organization was planned



RUNNING EAST of the coastal mountains, the DBR is linked with other important telephone lines

and staffed by the P. T. & T. to handle the major part of the job in northern California and Nevada.

A Big Job Undertaken

THE OVER-ALL PROJECT, from Yakima, Wash., to Danby, Cal., was to build the 892 miles of new pole line, string 7,700 pair miles of wire, construct nine new buildings and two building additions, and install additional central office equipment, including carrier and repeater apparatus. The new pole line comprised 707 miles in northern California and Nevada, 90 miles in Washington, 30 miles in Oregon, and 65 miles in southern California. Additional crossarms and from two to eight new pairs of wires were placed on 425 miles of existing pole lines.

The first step was to survey a route from Klamath Falls, Oregon, to Las Vegas, Nevada. The lay of the land was detailed by a photographic reconnaissance made from a plane. With one pilot flying north from Reno, and another south, photographs were made of every foot of the route. Taken from pre-determined altitudes of from 17,000 to 22,000 feet, these bird's-eye views showed just about everything; in fact, they proved so detailed that seemingly invisible markings of section corners and claims could readily be seen, when magnified and viewed stereoscopically. So closely did the completed line follow the path selected from the pictorial survey, that 95 per cent of the original route was unchanged.

The first use made of the aerial photographs was to study the route for rough spots, such as hills, mountain passes, canyons, and sinks, for they pictured a "condensed Nevada

desert" in detail never before available.

The next survey step was to stake the line, following the path of the aerial survey. Operating from bases at four towns in which living accommodations were obtainable, a force of 55 men footed it over their sections of the route. These men were immediately faced with the problem imposed by vast distances which are particularly impressive, not to say awe-inspiring, in sparsely-populated Nevada. A motor ride of some 60 miles to work in the morning, and home at night, was commonplace; the reason being, of course, that communities are very scarce, particularly away from established roads.

Although the survey went ahead rapidly, the engineers were sometimes in sight of the motorized telephone construction outfits which were following them. So close, in fact, that one chain man complained that "he hardly had time to get his hand out of the way" before a mechanical digger would be there to put a hole in. There was much good-natured banter between surveyors and construction men on this score; the latter claiming that the stakes were driven wherever there was sand—regardless of whether there was solid rock six inches under the surface or the stakes were propped up with stones if the sand was not deep enough! This was desert humor, for which there was daily need.

In the meantime, telephone engineers made estimates of the number of poles and the quantity of wire, hardware, and other material which would be needed. This was followed

THE TELEPHONE ROAD. Built by telephone men in order to build the pole line, it stretches north and south as far as the eye can see

by estimates of required repeater and carrier equipment and allied items. Orders were placed with the Western Electric Company, and wheels began turning at top speed in all parts of the country to make and send needed equipment and materials.

Full Speed Ahead!

THE PROJECT'S division construction office was opened in Reno with a complete staff of experienced telephone people. Every man in charge of a specified job—ordering materials, handling vouchers, bills, payrolls, hiring labor, etc.—was an expert of at least 15 years' Bell System experience in such work. This proficiency paid liberal returns on a job where know-how was vitally necessary, for there were many irons in the fire at the same time.

Before the construction stage of the project could be started, necessary approvals had to be obtained, priorities arranged, engineering plans completed, materials ordered and shipped, right-of-way problems investigated, and men, vehicles, and tools provided. There was the further need for establishing camps, pole yards, and bases for trans-shipment of freight from railroad cars to trucks.

The Pacific Company's territory is divided into four operating areas, whose names indicate their respective locations: the Washington-Idaho area; Oregon area; Northern California and Nevada area; and the Southern California area. Each area handled its own share of building the line.

The 707 miles of main and side leads in California and Nevada were divided into three districts and ten equal work sections; "equal" meaning a fair division of the work rather than distance, for some had rougher country than others. The longest section measured 82 miles, and the shortest 43 miles.

The construction force reached 640 employees at the peak, and averaged 522 men and women, including office people, to fill jobs ranging from division construction superintendent to temporary laborer. The Northern California and Nevada area was able to furnish all but 23 foremen and 112 linemen, and solved the problem of temporary laborers by recruiting junior college and high school boys for their summer vacation.

As none of the other Pacific Company areas was in a position to spare men, arrangements were made with the Bell System at large for personnel on a loan basis. The job thus became more than ever a Bell System family venture, the requisite number of foremen and linemen being borrowed from the Northwestern Bell Telephone Company, the Southwestern Bell Telephone Company, the Mountain States Telephone and Telegraph Company, the Illinois Bell Telephone Company, and the A. T. & T. Long Lines Department.

The temporary laborers were, in general, students from junior colleges and the California state agricultural school. A majority were husky members of football squads and—as was desired—accustomed to a hot, dry climate.

THE NEXT THING was to line up enough motor vehicles: a difficult assignment in war days, with every truck and tire as precious as a jewel. When the field had been looked over, it was found that all of the 123 cars

and trucks required could be furnished from the Pacific Company fleet, or purchased or rented on the coast, except for ten 1½-ton winch- and four 2½-ton digger-equipped trucks.

Here, again, the problem's solution became a Bell System family matter when the needed vehicles were borrowed from the Mountain States, Northwestern, Wisconsin, Ohio, Southern, and New Jersey companies and Long Lines. The trucks arrived in Nevada in good condition, newly painted, and ready to go when rolled from the freight cars—but destined to have this bloom of mechanical beauty soon removed by desert wind and sand.

By April 16, 1942, basic line material requirements had been figured and were set at: 30,000 poles, or about 300 carloads; 64,000 crossarms, about 54 carloads; 1,589,000 pounds, or more than 30 carloads, of line wire; and 1,000 anchors.

On a project of this size and urgency, ordinary routine would not produce desired results. While the usual practice is to order all stocked material on a single requisition, this line required quantities far greater than were carried by the Western Electric Company distributing house at Emeryville, California. "W.E.," therefore, placed many of the orders for direct shipment from the factories, and furnished the Pacific Company with groupings of items which could be ordered directly from individual suppliers with minimum handling and bookkeeping. W.E. also assigned the project a special block of requisition numbers which would enable the Reno office to have the numbered originator's copy for quick reference at all times, instead of having to send it to supplies headquarters

A typical supply dump beside the railroad in Nevada

The Service of Supply

THE JOB of the service of supply for the project was of such proportions as to make even veterans of other big telephone construction jobs wonder just how objectives were to be reached by scheduled dates. The fact remains that the line was completed well in advance of original "deadlines."

for numbering. This improvisation proved highly valuable, and was representative of the "Let's get the job done" coöperation shown by Western Electric people everywhere.

Supply control centered in Reno. Reports from the field and shipping information from Western Electric were coördinated through constant teletype communication with the telephone company supplies superintendent at Emeryville.

DIGGING POLE HOLES by hand in lava-boulder country

Getting poles on the construction scene was in itself a tremendous task, and the suppliers teamed up with railroads and others concerned to do a really fine job. Every hour in transit of the initial supply of creosoted pine poles from Mississippi and Texas was followed by telegraph. The whereabouts of each carload was known at project headquarters at all times, even though the rail lines were handling war traffic of unprecedented proportions. And when shipments of cedar poles from the northwest were held up because of heavy rains in the forests, there was some necessarily last-second routing of pole shipments to railheads of the various construction sections. To accomplish this emergency cutting out and switching, the freight cars had to be located while still east of Salt Lake City.

A steady flow of supplies was maintained with minimum waste of time and motion. The supervising construction foremen kept the project offices in close touch with supply requirements in the field, so that no critical shortages could develop in any of the sections. In fact, the foremen walked every inch of their sections in taking inventory of the material already in plant. How well this work was carried out is shown by the fact that all sections completed their share at the same time.

Construction Starts

THE SURVEY for the line was started on April 25, 1942, and the last stake driven on August 20. The first pole was set on June 15. The first step of construction work, which was to set poles equipped with crossarms and hardware, string wire for the top arm of the main lead, and build two side leads, was completed on August 31. The second step, of installing a second arm and wire and building a difficult branch pole line to Bishop, Cal.,

was completed on October 15. Final clean-up work was out of the way by November 20, and the project office was closed on December 1. From north to south, the job came out "even": the engineering and construction outfits met their schedules; all of the many repeater stations were built, equipped, and ready; the circuits were opened for service at the time planned!

Pioneers in the Wilderness

IN THE COUNTRY traversed by the pole line, all of the mountain ranges and valleys run north and south, and there are innumerable dry lake beds and stream courses. A major part of the pole line is located above 4500-foot elevation. The range in climate and temperature on the route is extreme. On one day, snow fell along the northern California section while thermometers in southern Nevada soared to 109 degrees above. There was snow and sleet in the vicinity of Reno as late as June.

The members of the telephone crews were true pioneers in this limitless wilderness. Before trucks and machine diggers could get through to spot poles and gouge holes, a road had to be built. Bulldozers scooped away brush, small trees, rocks and sand. Trucks following this trail packed the surface into a passable road, except where the sand seemed to "go as deep as China."

The road and the telephone line are inseparable. They stretch through the forests and over the desert, as far as eye can see. Occasionally, where a particularly steep hill blocks the way, the poles march on over the crest while the road skirts the slope, in respect to the force of gravity and the limitations of mechanized equipment, however powerful. As time passes, the road will again be covered by sagebrush, and there may come a day when travelers will ask, "What road is that, and where does it go?" The proper answer by a historically-posted person will be, "That's the road built by the telephone fellows, back in '42 during the war. It leads north and south."

DUST HUNG HEAVY over construction operations almost everywhere

The line construction work entailed five principal operations: 1. digging pole holes; 2. setting the poles; 3. straightening and aligning the

A HINGED "sand barrel" helped in setting poles in loose sand

poles; 4. stringing the wires; 5. sagging the wires.

The Going Was Tough

POLE HOLE digging throughout the job proved more difficult than had been expected. Blasting operations for some 3,000 holes required over 13,000 pounds of explosives; or, otherwise expressed, holes for about 80 pole-line miles were blasted. In lava rock country, as many as 40 sticks of dynamite were used to blast one pole hole, and a 25-stick charge was not unusual.

Machine digging proved not too successful, as either rock or sand was encountered everywhere. In some places the surface was covered with material resembling fine ashes. When a machine digger was used, the men raked away gravel, sand, and rock brought up by the auger, to keep the hole from filling up. Even then, it was necessary to clean out most excavations by hand. In addition, at least 4,000 holes had to be dug entirely by hand, due to the nature of the surface or location of the job. Air compressors and integral gasoline engine drills were widely used. The holes were dug from 5½ to six feet deep and often would be five or six feet in diameter at completion, due to cave-ins.

Where water was close to the surface (there were three such places on the entire route), or in regions of deep sand and gravel, sand-barrels were used to keep the walls of the excavations from collapsing before a pole could be set. Sometimes a bulldozer would be used to dig a pit large enough for a cellar, in order that the sand barrel could be set at proper depth.

Wooden cribbing was built to protect poles on crossings of stream beds which were usually dry but apt to become torrents after cloudbursts and mountain thaws. Laced together with steel rods and wires, the cribbing was filled with rocks to form strong bulwarks against the storm waters and debris.

Copper-steel wire was substituted for copper wire, and effected a sizeable saving in this war-precious metal. The price, in this case, was a closer spacing of repeater stations on the line, since transmission losses prove greater when copper wire is not used. Large-scale changes of plans and materials put a heavy load on the supply

organization and Western Electric, of course; but everybody came through handsomely to help make effective these desirable though costly economies of scarce materials.

"*Spotting*" *Supplies*

POLES were delivered to the various railside yards of the project, and from there trucked to their locations, often more than 100 miles. Trucks equipped with derricks made easy work of loading the big sticks—although in one section, when a derrick broke down, a cowboy was employed to hitch his horse to a rope and roll the poles up skids aboard the truck. The results were satisfactory, although local progress was slowed somewhat.

Ordinarily, the truckloads of poles would be hauled along the "telephone" road and each pole unloaded at its site. In exceptionally inaccessible country, the telephone men carried the poles by main strength from roadside to the desired location. In other places, it was possible to attach a rigging to a boulder high on a hillside and, by use of a winch, "highline" the pole over obstructions. Elsewhere, tractors often "snaked" poles to the proper spots.

In the wake of the poles came truckloads of crossarms, which had been fitted with pins at the pole yard, and supplies of insulators and pole line hardware. The telephone crew, following closely, fitted each pole with crossarms and insulators and placed it in its hole. The raising was done when possible with the aid of a derrick, but in places where truck or tractor could not go, pike poles were used.

Next came men to straighten the poles and line them up with the rest of the lead. They, along with the other construction men, did their work so quickly and so smoothly that the pole line rose magically wherever the gang was at work.

With the poles in place, along came a truck carrying wire reels adjusted on a mechanism for "throwing" desired arrangements of wires for transpositions. While being unreeled, the wires were kept separated by various means, most often by threading them through rings on a stick carried by a man walking behind the truck.

At the end of the big construction parade came the wire-sagging crew. It was the work of these linemen to

IT WAS sometimes necessary to pull wire by hand in mountainous country

adjust precisely the sag or slack in the wires, in accordance with tables set up for various temperatures and span lengths. The extremes of heat and cold along the route made this operation exceedingly important. The men illustrate this point by telling how the "dead-end" or tension pole, placed in one section of the line at the end of a day's work, was plucked right out of the sand when night's work, pridefully, "the many wires look just like a slender tube of copper."

The sagging was done by adjusting the slack in the wires until the desired tautness was obtained. Briefly, the process was as follows:—The linemen on the poles were in touch by telephone with the tension man at the end of the sag section, who regulated the slack in the wires by adjusting "slack

LAYING UP THE WIRE. The men on the poles are lowering ropes by which to pull up the unreeled wire

coolness caused the wires to contract.

Sagging was an exacting job because of the types of transposition and carrier systems used for service over the lead. The level of wire was not allowed to vary more than three-quarters of an inch per wire at any point between poles, except at transposition brackets, where the top wire is about one inch higher. "Viewed from the side," said the chief of this pullers" and tackle according to directions. The foreman, standing on the ground, directed sag adjustments from information obtained by timing with a stop-watch the oscillations of the wires. Further adjustment was made in individual pairs until the wires pulsed together five times in ten seconds, indicating a tension not exceeding one-quarter inch variation.

A big problem linked up with all

phases of line construction had to do with keeping the motor vehicles in repair and on the job. The rough terrain, together with abrasive dust and extreme heat, made regular maintenance a vital necessity.

There were many difficulties to be met in keeping enough of the fleet in operation to carry the men to and from work. This was due, in large part, to tire replacement rules and to the job by the telephone company's motor vehicle department. The light trucks used by these men were well equipped with tools, pneumatic grease guns, and air compressors. Great care was taken to keep the tires of all vehicles properly inflated.

An innovation required throughout the desert country was a non-corrosive type of anchor for pole guy rods. Chemicals in the soil eat away the

SAGGING THE WIRE. In this precision operation the foreman, on the ground, times the wires' oscillations with a stop watch

regulations which often forced vehicles out of service for as long as two or three weeks at a time, and to the fact that repair shops were available at only four widely separated towns on the entire route. These shops were always busy, so that the telephone trucks had to "join the crowd" and wait their turn.

Repairs to the digger trucks were made by inspector repairmen assigned unprotected metal anchors and rods to pin thickness in two or three years. The "desert-type" anchor, made on the job, consists of a hollow block of concrete tapering to a broad base. Guy rods are covered with a tarry solution and wrapped with protective layers of paper tape. Next, the rods are inserted in the anchors. Then, with the aid of an ordinary tea kettle, the anchor is filled with the molten

ONE OF THE construction camps in the desert

solution, which completely encases the end of the metal guy rod, hardens, and makes the unit impervious to chemical action.

Whatever the problem to be solved, the gang developed a "won't be licked" spirit. They accepted seemingly impossible due-dates as a matter of course.

Interest of the men centered around the job, and there was plenty of rivalry between crews of adjoining sections to be the first to complete the work. The weekly progress of construction was charted in graphs made up by each of the supervising foremen, and the rise and fall of the columns for hole digging, pole setting, wire stringing, etc., brought forth not only the puffed chests of prideful accomplishment but also wails of dismay. Every foreman, it should be explained, was convinced that his was the toughest section in the entire route. And there were a few places on each section which convinced its foreman that he was right. There were plenty of times when the predicament of a neighboring outfit would bring chuckles of understanding: that would be, perhaps, when a foreman's crew had gone swiftly for miles down a straight and easy stretch with all phases of construction, only to reach a range of rocky hills or a boggy sink, where every pole hole was a major operation.

Home on the Range

THE CONSTRUCTION CAMPS were an integral part of the project, and were important to its success, since good living conditions for the men were needed to counteract isolation and the discomforts associated with desert life in summer. A commissary company was engaged to operate the camps, agreeing to furnish food of high quality and sufficient quantity to satisfy active and hungry men, and to make living conditions as pleasant as desert life permits.

The typical camp was made up of wooden buildings similar to the structures in today's Army camps. There was a barracks for the telephone crew and one for the cook's crew; a mess hall and kitchen; an air-cooled recreation hall fitted with games, tables, and benches; a storeroom, a tool house, bath house and washrooms. Water was hauled to camp in tank trucks.

The use of wooden buildings, rather than tents, was determined by the extremes of temperature experienced, and the wind and sand storms prevalent in summer. The sand storms were like dry, hot blizzards, during which the air would be so filled

with sand that it was almost impossible to find the way from one building to another, and the wind was a destructive and painful sandblast. In late summer there were the usual cloudbursts of high altitudes which built up streams and torrents in a minute's time, only to vanish as quickly.

Very few—only about 15 or 20 out of 400 temporary men—quit the job before their respective sections of line were completed. All members of the 23 crews from eastern companies were experienced telephone men; but, by and large, out of 50 or 60 men at a camp, only about 20 were regular telephone employees, and many of these had been with the company for less than a year.

The older men shared their "know-how" of telephone work, and let the young fellows have their fun at day's end. The boys, it should be said, ran true to form in vitality, and thought nothing of a ball game right after supper, regardless of what hard work had been done. Chief wonder, however, was their limitless capacity for food. The mess halls served more than 81,000 meals. Vouched for by the plant operating assistant in charge of camps, and plenty of witnesses, is the fact that 50 men in one of the camps drank 25 gallons of milk in one evening! The usual daily intake for a camp was 25 gallons of milk and 25 gallons of lemonade.

The men who lived in towns along the route had the advantage of seeing other people, attending movies, and being a part of community life. Where accommodations were satisfactory, they were given room and board in hotels. One crew was quartered in a small town's one hotel and fed in a mess hall set up by the telephone company. It was here that the postmaster organized a baseball team made up entirely of telephone boys, who won all 12 games played with teams from far and wide, including some crack service teams.

THE JOB had a safety record worth talking about. The engineering de-

GOOD AND PLENTIFUL FOOD for hearty appetites was provided in the mess shacks

partment did not have one lost-time accident. The construction department had only two comparatively minor lost-time accidents. This despite that fact that the new men, while in excellent physical condition, were not used to construction work or versed in safety methods. New men are always more prone to accident than their experienced fellows. The good showing made indicates that everybody followed closely the Bell System's safety motto: "No job is so important and no service is so urgent that we cannot take time to perform our work safely."

The draft was a cause for some concern, in that employees were constantly being called for physical examination and induction. The situation was helped somewhat, for the men themselves, when arrangements were made for transfer of records from home-town selective service boards to a board nearest the place they worked. The continual drain of help from the job imposed a great many problems for the telephone organization, however, since the labor turnover due to the draft was considerable.

The men who worked on the DBR project were "tops" in every respect. Never was there dissension in any camp, and they seemed to have a mutual understanding that enabled them to get along famously with one another. After the project was completed and the men had gone home, the parents of nearly 100 of the boys communicated with company supervisors to say how much they appreciated the good treatment and care their boys had received.

A SUMMING UP of the spirit of the personnel and its accomplishment is best made by the division construction superintendent, who knew them all on a first-name basis. He said:

"The question has been raised several times as to how it was possible for this construction organization, composed as it was of so many new people, to accomplish the work that has been done and to meet all of its objectives on time. The only answer is that each individual on the job, and particularly all those chosen for key positions, accomplished all that could have been reasonably expected—and more. To their loyalty, courage, and hard work our company owes the accomplishment of the objective requested. Associated Company personnel cannot be praised too highly; they were rugged, experienced construction men, especially picked by their home people for their ability, and they arrived imbued with determination to do a good job. The sentiments of the entire gang can probably be best expressed by their often repeated hope to be in on the next big one."

The Bell System Pioneered in Providing Facilities Which Made Network Broadcasting Possible, and It Can Provide Them for Post-War Frequency-modulation Programs

FM Program Transmission: A Bell System Service

The A. T. and T. Company recently prepared a booklet, bearing the above title, for the information of people in the radio broadcasting industry and others having a special interest in the subject. The subject is also of interest to many people in the communications industry, and the booklet is therefore reprinted here. Modulation, and the difference between the usual kind of broadcasting and frequency-modulation broadcasting, may seem fairly complicated matters to the non-technical reader, however; and a simple explanation of them, in the form of a letter to a friend who had asked for enlightenment, may serve as a helpful introduction.

DEAR PETE:

You asked me what FM is; and, when I said that it was FREQUENCY MODULATION, you said, "First, what is MODULATION?" Let's try to clear up this question. Here goes.

MODULATION is the variation of the characteristics of an electric current or wave to enable it to carry intelligence.

Now don't let that scare you. Let's consider an example. In the simplest telegraph circuit, signaling is accomplished by the operation of a telegraph key which controls the current flow from the battery. When the operator presses this key, the current flows; and when he releases it, the current stops. The electric current in this simple telegraph circuit is turned on and shut off by this key much as the flow of water is controlled by turning on and off a faucet. We may say that the flow of current is MODULATED by the operation of the key, or broken up into short or long parts called dots and dashes which are employed for the transmission of messages.

MODULATION, in most cases, is not simply turning the current on and off. Just as a faucet may be adjusted to any position between closed and wide open to produce any desired flow of

water, so the flow of electric current can, with suitable devices, be similarly controlled. A telephone transmitter or microphone is one device which enables such control of a current to be accomplished, the strength of the current being controlled by the pressure of the sound waves reaching the instrument. In a simple telephone circuit, the strength of the current from a battery is so controlled; this current may be said to be MODULATED by the sound waves, and its strength at any instant is a measure of the pressure of the sound waves reaching the transmitter or microphone.

IN THE antenna of an ordinary radio broadcasting station we have a different kind of current; not a battery current, but a high-frequency alternating current. This current is similar to the alternating current used for house lighting and power purposes, except that instead of flowing back and forth 60 times per second, as such currents do, it races up and down the antenna hundreds of thousands of times per second. The number of to-and-fro excursions or "cycles" per second is called the frequency of the current, and in ordinary broadcasting stations is between 500,000 and 1,600,000 cycles per second.

The current from the microphone in the studio of the transmitting station is, however, similar in character to the current in the simple telephone circuit which we have considered. This telephone current is employed to control the strength of the high-frequency current in the broadcasting station antenna. We say, then, that the antenna current has been MODULATED by the music or voice. Its strength follows the variations in sound in the studio just as the strength of the battery current follows the variations of the voice in a simple telephone circuit. The waves radiated from the antenna similarly carry these relative variations in strength, or amplitude.

SO FAR, we have been talking only about the kind of MODULATION where the strength, or amplitude, of electric currents, or waves, is varied; and this is AMPLITUDE MODULATION. There are other kinds of MODULATION, the best known of which is FM, or FREQUENCY MODULATION, about which you were asking. We have already considered the fact that the current in a broadcasting station antenna is a high-frequency alternating current. The waves radiated from the antenna are, similarly, high-frequency waves. In the case of FREQUENCY MODULATION, the frequency of the antenna current, and consequently the frequency of the waves that it sets up in space, are varied instead of their strength, or amplitude.

When no modulation is taking place, the frequency of the waves radiated by the broadcasting station antenna remains constant at the assigned value. For example, if such a station were assigned a frequency of 45 million cycles, the current in its antenna would continue to surge back and forth in the antenna 45 million times each second as long as there was no modulation taking place. However, when the announcer spoke or music was played, the frequency would dance about, each change in sound pressure which reaches the studio microphone causing a change in fre-

quency of antenna current to occur. The antenna current in the radiated waves would then no longer have the constant value of 45 million cycles, but would vary through a range from about 44.95 to 45.05 million cycles. The antenna current and the waves are then said to be FREQUENCY MODULATED. Their strength or amplitude remains unchanged, the intelligence in this case being transmitted by means of varying the frequency.

At the receiving point, a circuit arrangement in the radio receiver called a "discriminator" converts the variations in frequency back to changes in current strength, and the loud speaker in the receiver converts these into pressure changes in the air. The end result is a sound wave having characteristics like those of the sound wave that reached the microphone in the broadcast studio.

As FREQUENCY MODULATION systems transmit intelligence by changes in frequency, receivers used with this type of transmission may be designed to be responsive primarily to such changes and to respond very little to changes in radio signal strength. This serves to reduce greatly the noise, or "static," due to the radio receiver picking up extraneous electric waves, and is one of the important reasons for the present great interest in the use of the FREQUENCY MODULATION system.

This may not make the matter as clear as spring water, but it's the best I can do here and now. To go further, it would be necessary to employ diagrams and use mathematics. If you want me to do this, let me know, and I'll give you the works.

As ever,

GEORGE

ONLY ABOUT 20 years ago, network radio broadcasting was an unknown art. Today, radio listeners everywhere can hear the same program at the same time. The Bell Telephone System pioneered in this development by designing and furnishing wire circuits over which programs could be distributed to many radio stations simultaneously. At the present time, the System maintains and operates more than 130,000 miles of these "program transmission" circuits, interconnecting radio stations regionally and from coast to coast.

Now comes an important development in radio: Frequency Modulation. Today, networks for FM broadcasting are in their infancy, just about where the first networks were 20 years ago. And once again the Bell System is prepared to contribute its knowledge and experience to the service of the broadcasting industry.

Nobody can say exactly what FM will do in the next 20 years. However, FM broadcasters should know that the Bell System is prepared to meet their post-war needs for studio-transmitter links, for circuits connecting FM stations in regional or nationwide networks, and for local channels required to pick up programs originating outside of the main broadcasting studios.

Bell System facilities for these purposes have been tried and tested. They will meet all present and future

BELL SYSTEM routes over which frequencies of 15,000 cycles or more are now transmitted for telephone purposes. Such lines can be used for 15,000-cycle program circuits by adding suitable terminal equipment

needs of FM broadcasters with respect to fidelity of transmission, freedom from noise, and control of distortion.

15,000-Cycle Circuits?—Yes

TO WHAT extent will FM stations be grouped to form separate networks? What quality of inter-city channels will these networks require? The answers to these questions will of course be determined by the broadcasting industry itself. Whatever is decided, the Bell System will be able to furnish inter-city circuits of the kind needed, including 15,000-cycle circuits if they are desired.

The Bell System is already furnishing 15,000-cycle channels for studio-transmitter links to the majority of all FM stations now in operation. These are giving satisfactory performance, demonstrating through practical experience that reliable arrangements can be provided.

Studio-Transmitter Links

ENGINEERING standards established by the Federal Communications Commission for FM broadcasting specify that a frequency band of 15,000 cycles must be transmitted from a station's main studio to its transmitter.

In general, FM transmitting stations are located either within cities on tall buildings, or near cities on hilltops or mountain peaks.

In the first case, the distance between studio and transmitter is usually short, and no special construction or transmission problems are involved in providing a satisfactory wire channel.

When transmitters are located at more remote points, some special con-

struction may be required to establish the channel. So far as transmission requirements are concerned, the Bell System can readily meet them. At the start of the war, 15,000-cycle channels were being provided to some 20 FM stations over distances ranging up to about 25 miles. When the circuit is less than 8 or 10 miles long, intermediate amplifiers are not usually needed. Longer circuits differ from those ordinarily provided to standard broadcast stations principally in that additional intermediate amplifiers are required.

Beside furnishing such 15,000-cycle links to FM stations, the Bell System has for years provided many other broadcasting stations with studio-transmitter channels transmitting up to 10,000, 12,000 and 15,000 cycles. This emphasizes the fact that FM in itself presents no new problems. There is, indeed, no question that the Bell System can render FM broadcasters a service which meets the test of economy and at the same time fulfills all requirements of performance.

Network Circuits for FM *Stations*

AT PRESENT, regular network facilities in general use by broadcasters are being employed to bring distant programs to FM stations. There are strong indications, however, that the number of FM stations will greatly

increase in the immediate post-war period. Furthermore, it may well be that separate networks for FM broadcasting, using program sources of their own, will be desirable on a regional and eventually on a country-wide basis.

Whatever pattern emerges in the future, the broadcasting industry is entitled today to know the answer to this question:

Can the industry rely on the Bell System to provide program transmission channels which will preserve for FM network broadcasting the advantages of high fidelity, and freedom from noise and distortion, which are

characteristic of the Frequency Modulation method?

The answer is emphatically *yes*.

For many years, wide frequency bands have been transmitted over long distance telephone carrier systems which make it possible to send many telephone and telegraph messages over a single pair of metal conductors. The map on page 258 indicates the extent of present Bell System facilities which now are capable of transmitting frequencies of 15,000 cycles or higher for telephone purposes. On many other routes also, circuits can be so equipped if they are needed.

To adapt these lines for 15,000-cycle program circuits requires addition of special terminal equipment. The dates on which such equipment can be provided will depend largely on how soon materials and manpower become available for its manufacture. It is expected, however, that the Bell System will be able to keep pace with the growth of FM stations and their need for channels of this quality.

Progress Through the Years

BEGINNING with the pioneer days of network broadcasting, and through the years, the System has kept pace with—has, in fact, anticipated—the needs of broadcasters for network channels.

In accordance with the indicated preference of the broadcasting industry, the main sections of the wire channels furnished by the System for network broadcasting were set up to transmit a frequency band about 5,000 cycles in width. For 10 years before the war, however, in anticipation of possible future needs, all program transmission facilities installed by the telephone companies were generally designed to be adaptable to the transmission of frequencies up to 8,000 cycles. Early in 1941, when broadcasters evidenced interest in improving the quality of transmission over nationwide networks, the System offered 8,000-cycle channels. Shortly thereafter, war imposed limitations on the use of materials for this purpose. There is no other limitation, however, on the System's ability to provide circuits of 8,000 cycles or more.

As early as 1933—more than a decade ago—the System successfully transmitted frequency bands up to 15,000 cycles over circuits between

Philadelphia and Washington. These experimental circuits were set up to transmit to Constitution Hall, in Washington, a symphony concert produced in Philadelphia by the Philadelphia Orchestra. Practically the entire audible range of musical tone was transmitted. At that time the System announced that circuits of the type employed, "while not now available for use on a country-wide basis, can be made available should commercial requirements develop."

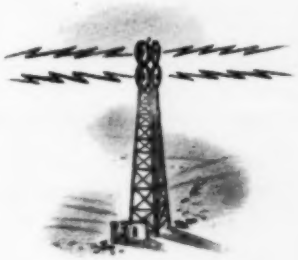
Eight years later, in the winter of 1941, the Bell System demonstrated the relative quality of transmission of 5,000-, 8,000-, and 15,000-cycle frequency bands over a 2,000-mile circuit. This demonstration was before the American Institute of Electrical Engineers. The 5,000- and 8,000-cycle circuits were of the type now used in program transmission. The 15,000-cycle circuit employed a standard carrier telephone system to which had been added special terminal equipment—equipment expressly developed for 15,000-cycle network service should the need arise. It is this type of circuit which the System will have widely available in the postwar period to serve broadcasters who may have need for 15,000-cycle intercity channels.

Local Pick-Up Channels

FOR FM PROGRAMS originating outside of the studio, local circuits within cities and metropolitan areas can be provided to connect the broadcasting point with the station's fixed facilities. On these circuits, frequencies up to 15,000 cycles can be transmitted by adapting regular telephone plant for program use. Such channels, meeting rigid noise requirements, have already been provided for some of the FM broadcasting stations.

Wire or Radio Links?

SO FAR, we have been speaking of wire circuits to transmit FM programs. However, if other means should prove better or more economical, the Bell System will use them. The System is in the communications business and will use the best means that can be developed, whether wire or radio, for transmitting broadcast programs as well as other forms of communication.



One evidence of this is the American Telephone and Telegraph Company's current undertaking to build a radio-relay system between New York and Boston. This trial installation is of a type which was under development by the Bell Telephone Laboratories before the war. It applies to radio communication many of the techniques which have played an important part in the development of long distance telephony. Directed radio beams at ultra-high frequencies will operate simultaneously in both directions, and will be relayed at stations about 30 miles apart.

The purpose of the trial is to learn from actual experience the relative advantages and disadvantages of

broad-band transmission by radio, compared with other means. This purpose applies to the transmission of various types of communications, including long distance telephone messages, television, and broadcast programs.

For FM broadcasters—in fact, for all broadcasters—the experiment will help greatly to define the relative merits of wire and radio channels for program transmission. There is no doubt that wire facilities give dependable, satisfactory service at reasonable cost. The question to be settled is, "Can radio-relay links give equally good, or better and more economical, service?" The Bell System expects to answer this question with facts drawn from experience.

WHAT HAS BEEN SAID in this booklet reflects an important objective of the Bell System—to do everything it can to further the progress of broadcasting operations everywhere. The System's intensive study of the characteristics of sound; its research toward finding and using the best methods of transforming these sounds into electrical impulses and transmitting them clearly over great distances; its vast physical facilities available for this purpose; and, not least, the wealth of experience and skill acquired in the operation of nationwide program networks over a long period—all these give assurance of future service to the broadcasting industry that will be of increasing value to broadcasters and the public.

IN A recent landing operation against a Jap-held stronghold in the Pacific, our Navy used 700 to 800 warships. These vessels were equipped with 48,166 telephones, according to Navy Department estimates, and these shipboard telephones were connected by some 5,000,000 feet of telephone cable of various sizes. The 48,166 telephones involved in that one naval operation are about equal to the number serving a city the size of Flint, Michigan, or Youngstown, Ohio.

Here is dramatic evidence of the vast quantities of communications equipment required to wage global war. It assumes even greater proportions when the single operation is multiplied many times over by equally large naval units in action on both sides of the globe. Added to the Navy's requirements are the tremendous communications needs of the Army's ground and air forces and of stationary installations around the world.

The Navy figures help to answer the question of why telephone facilities are scarce on the home front. They indicate something of the additional amounts of equipment which will be required before the war against Japan is won.

An Allegory about Diamonds Leads into a Non-technical Exposition of the Many Factors of Toll Circuit Engineering Which Affect Provision of a Nation-wide Network

Providing Paths for Long Distance Calls

Ralph I. Mabbs

JOHN dialed "Long Distance" with incisive strokes. He was calling Gramp out in Arkansas. Gramp was probably in the shed by the barn, perhaps repairing a toy for the kid up the way. Gram would have to go out and call him, but John had to talk with him. This was to be no personal telephone call, but an honest-to-goodness war call—an important one. John was playing a hunch.

Diamonds! Not the jewelry kind necessarily, but diamond points for cutting tools, were needed in John's war plant, and maybe Gramp could help. A small package of them, all the plant possessed, had been lost—or stolen. Unless he could locate some soon the plant would have to shut down. Big Town, near which his plant was located, had been scoured with no success, but Gramp . . .

A little brook tumbled down across the barren black rocks on a remote corner of Gramp's farm. It wasn't this that stirred John's boyhood memory, but Gramp's story of how he found among the black pebbles on its clear bottom one or two small heavy stones each year, some of them worn bright and sparkling. Could they have been diamonds? Gramp never knew, but it was worth a try to find out.

John knew that the long distance lines were extra busy these days, but he didn't know that a storm had broken a telephone line normally used to reach Gramp's town hundreds of miles away. Would that mean no path for this important call? Let's see.

To the operator's answering "Long Distance," John replied, "I want to get Burnt Rock, Arkansas, 475-ring-3."

"Routes to Burnt Rock, Arkansas?" John heard, and knew his operator was now asking a route operator how

Yes, diamonds *are* found in Arkansas. More than 10,000 have been found in Pike County one of more than 40 carats.

to reach Burnt Rock. "TC Little Rock via Memphis, 'A' route St. Louis," came the reply.

Then John heard his long distance operator say to a tandem operator, "Memphis."

Tandem, an intermediate operator who makes connection to the long distance circuits, came back with "OD and NC," which meant to the long distance operator that some of the circuits to Memphis were out of order and that all of the others were in use. She must try to reach Little Rock by way of St. Louis, as the route operator had instructed when she said "'A' (alternate) route, St. Louis."

John's operator, again to the tandem operator: "St. Louis."

In a moment he heard the St. Louis operator identify herself as "St. Louis."

John's operator then asked for Little Rock, and the Little Rock operator came in with "Little Rock."

The long distance operator passed on Gramp's telephone number, "Burnt Rock 475-ring-3," as given to her by John.

John listened with interest to this dialogue. He had heard it many times before, and it always gave him a feeling of pleasant anticipation as he seemed to feel himself advance nearer and nearer to Gramp's old farm.

Presently he heard the Burnt Rock operator identify herself, and Little Rock ordered, "475-ring-3." Softly came the intermittent hum of the ringing signal, and then Gram's familiar "Hello."

Easy? A turn of a dial, a buzz, an order given, a few seconds of dialogue between operators, a ringing signal, and a familiar voice. We recall that the long distance lines were extra busy and we haven't forgotten that a storm had disabled some of the telephone plant in the path of the call. Yet, there it is—well, I guess you can say it's easy.

Easy, because there were plans and experience and thought and study. Management, staffs, manufacturers, engineers, installers, operators, maintenance people, and the rest of the telephone team had worked together with one aim, that this call, representative of any call, might result promptly in a satisfactory connection.

How the Call Went Through

THE TELEPHONE CIRCUITS over which connections are made between Big Town and Burnt Rock had been distributed among several geographical routes, so that, should one of them become out of order, others between the same points still could be used. All John's operator had to do was to route the call around the trouble. When she learned the route via Memphis was not available, she tried by way of St. Louis—and got through.

To get the picture more clearly, let's turn to Fig. 1. We'll let *A* represent Big Town, from which John was calling, and we'll call the rural community near which Gramp's farm is located *L*. Long distance calls from *A* are handled by the Long Distance office in that city, and long distance connections to telephones in *L* are made by the Long Distance office at *K*. *K* is known as the toll center (abbreviated TC) for *L*. Thus, when the route operator at *A* prefixed "TC" she meant that Little Rock is the toll center which makes long distance connections to Burnt Rock.

The normal route of John's call, the one tried first by the operator at *A* to Gramp at *L*, is via *H*. If for any reason, however, the route by way of *H* is blocked, or all of the circuits are in use, calls are rerouted via *G*. That then explains what the route operator at *A* meant when she said, "'*A*' route St. Louis." If Burnt Rock could not be reached via Memphis, it might be reached by way of St. Louis—an alternate or '*A*' route.

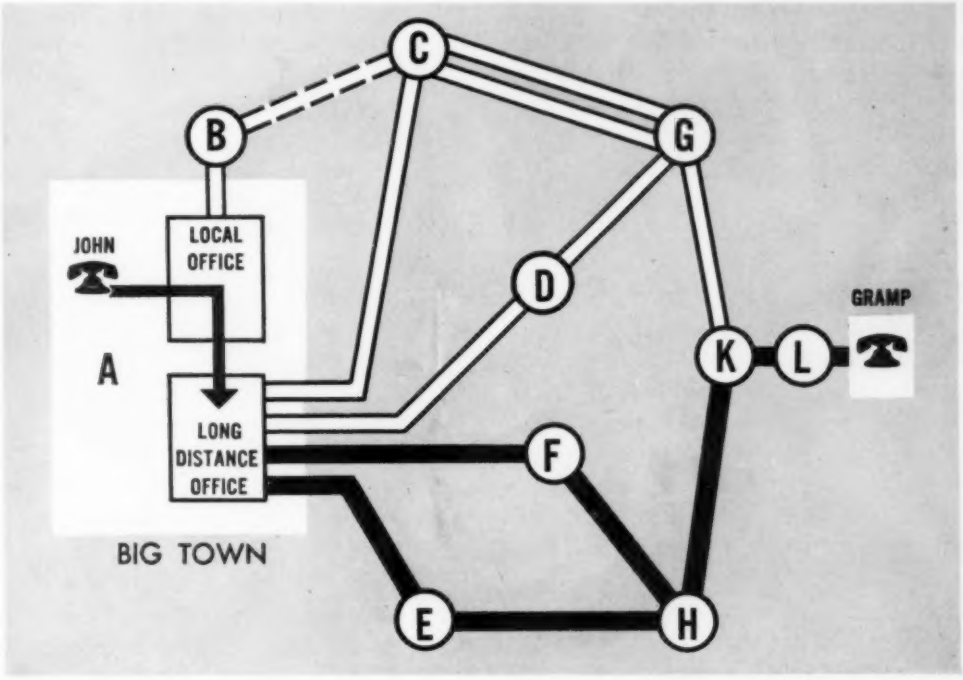


FIGURE 1. Routes available for John's call to Gramp

The circuits between *A* and *H* are shown in Fig. 1 as assigned to two different geographical routes, some through *E* and others through *F*. If, as in the case of John's call, one of the routes is out of service, circuits over the other route still can be used. This, of course, throws an unusual amount of traffic over the circuits on the other route. That is what the tandem operator meant when she reported "OD and NC"—abbreviations for "out of order" and "no circuit."

The alternate route via *G*, you will note, also is protected, because some of the circuits are routed via *C* and others via *D*. Although it is not always possible to assign the circuits between two cities to more than one route, the arrangements for rerouting calls over alternate routes, as well as the division of circuits among several geographical routes

where this is possible, very largely prevent the complete interruption of service between two cities except in the case of damage to plant over a very wide area.

Another important factor of protection also is illustrated in Fig. 1. At Big Town, *A*, we find both a local dial office and the Long Distance office. In *A*, as in all metropolitan areas, calls between the large city and the nearby smaller places such as *B* are normally handled by the local operator at the dial office, who makes connections directly with the adjacent city without going through the Long Distance office. Because there is a path for calls out of the city which doesn't involve the Long Distance office, protection is provided against isolation of the city should a disaster put the Long Distance office out of service. For example, the local operator could go through *B* to *C*, where connections may be had to other cities in the network of long distance circuits that covers the country. This is, however, an emergency route, and unsatisfactory for normal use.

Providing Just Enough Circuits

WE HAVE FOLLOWED the path of John's call from his Long Distance office to Gramp's farm, but what about the step between John's telephone and his Long Distance operator? Many others in Big Town no doubt were calling Long Distance at the same time that John was. It is necessary, therefore, to have more than one path from John's local office to Long Distance. The number required in order that all those who wish to reach Long Distance during the busier hours of the day can do so promptly had been calculated from estimates of the number of calls and from experience over many years regarding the percentage of telephones from which long distance calls will be placed at about the same time.

Here are some data about the paths from your telephone to Long Distance that may surprise you. They are normally provided in sufficient number so that during the busiest hour a signal appears before the long distance operator on 98 percent of the calls in less than three seconds; on the average for the total day a signal appears at Long Distance on 99.9 per cent of the calls within three seconds. During the busiest hour only about one call in a hundred should find all of the trunks to Long Distance busy, and for the total day only about one in a thousand should encounter this condition.

JOHN had been having difficulty in getting raw materials other than diamond tool points for his war plant. The telephone company no doubt was having the same difficulty, he thought. He wondered how many lines there were between his office and Gramp's farm; how the telephone company was able to foresee the number required at any particular future time, obtain the raw materials, manufacture them into wire and apparatus, install the facilities at the proper locations—and have them in service when needed even under war-time shortages of material and excessive volumes of calls.

It takes many months to manufacture and install long distance telephone circuits; but even before the circuits can be ordered from the manufacturer, the number of calls

they will be required to carry at any one time, and the average length of time that a circuit will be used on each call, must be estimated. In addition, there are often unusual load conditions, such as those resulting from a sudden storm, an armistice, or a World's Series, any of which may send the volume of calls sky-rocketing and overload the circuits. Plans must be made for these peaks.

Long distance circuits often cover great distances. Miles of cables and wire and hundreds of pieces of intricate apparatus and parts must be manufactured, rights of way obtained, poles set or conduits laid; special construction across rivers and over mountains must be planned; and additions to long distance offices and

". . . the long distance lines were extra busy." The number of toll and long distance conversations totaled 1,400,000,000 in 1944

Another factor to be considered, of course, is the calling habits of telephone users. Mondays and Fridays, for example, frequently are heavy days for business traffic, and in some offices as much as 15 percent of the total calls of the day regularly occur during one busy hour. Unusual cases have occurred where half of the calls on certain days were made during a two-hour period. Evenings and holidays, of course, are busy times for social calling.

their associated electrical equipment must be manufactured and installed with each new increase in the number of circuits.

It seemed clear to John that the speed with which his call could be completed depends upon the number of lines in each link of the connection. If there are enough to handle the volume of calls, then the connection would be made promptly; if too few,

then he would have to wait until someone else finished talking; if too many . . . but that would be wasteful and expensive!

Distance and Time Factors

IT IS AN interesting fact that the greater the distance between two telephones, the longer the average connection between them lasts. At 100 miles the average conversation lasts about four minutes, while at 3,000 miles the average is about seven minutes. Since the percentage of calls that encounter all circuits busy depends in part on the average duration of the calls, distance becomes a factor in determining the circuit requirements.

The number of circuits directly connecting two cities, the mere size itself of the circuit group, affects the number of additional circuits that must be added to care for each percentage increase in calls. To demonstrate this, consider a large and a small circuit group over both of which it is desired to give the same speed of service. With a large fully loaded group of, say, 25 circuits, calls are ending frequently and those waiting take their turn in reasonably rapid succession. In this case the circuits are kept almost continuously busy, because when a call ends the circuit is taken up immediately for use on the next call.

Now consider a small circuit group of, say, two circuits. When both circuits are busy and a third call is offered, the chance of a circuit becoming free promptly is very much less and the wait of the third call may be considerable. In order that the wait may be about the same as that on the larger group, more circuit time per call or fewer calls per circuit must be provided for on the smaller group. In consequence, the percentage of the time that the circuits in the small group are kept busy is much less than that for the large group.

The effect of group size is illustrated in Fig. 2. The telephone engineer uses just such a table as an easy means of finding the number of circuits required for various volumes of calls. This is only one of the several tables from which he chooses the one most representative of the service requirements for the circuit group he is considering. His tables, of course, are more complete, showing circuits from 1 to 50 or more. Note that the calls per circuit increase rapidly as the number of circuits increases and that the percentage of the time that the circuits may be used for a given grade of service likewise increases with the number of circuits.

Number of Circuits	*Number of Calls*	*% of Time Circuits May Be Used*	*Calls per Circuit*
2	14	58	7
7	63	75	9
25	254	85	10+

FIGURE 2. The effect of group size on the number of circuits required

Thus it is that the number of circuits between the towns and cities of the country is the result of a multitude of interrelated conditions and factors, some depending on the habits of the telephoning public, others upon intricate mathematical calculations, still others upon the elements of nature, and over-all upon the good judgment of telephone engineers and managements.

Engineering Problems

IT MIGHT be thought that in the orderly growth and expansion of the business and social life of the country, once the telephone plant had been built to fit its needs, all that remains to be done is to continue to expand as the need develops. Unfortunately, this is not the case. It is true that the long distance plant has evolved from a few circuits connecting the larger cities that are not too far apart to a network that permits the interconnection of all of the cities and towns in the country. The number of circuits between cities has grown with the demand for calls between the cities and the territory surrounding them. Where there were the greatest number of calls there came to be the largest number of circuits.

Business calls naturally occur most frequently between the large financial and industrial centers but, as more and more people installed telephones in their homes, the usage of the service for social purposes increased. Business calls are placed mostly in the daytime, while social calls tend to be more numerous in the evening. There is a tendency for social calls to reach out into the smaller cities and villages to a greater extent than do business calls. This is brought sharply to attention at such times as Thanksgiving and Christmas, when business calling decreases and social calling increases manyfold, building up heavy traffic loads to the small towns and filling the main trunk routes between large cities normally used for business calls.

Such sudden shifts in the distribution of traffic continuously present knotty problems to the telephone engineers who rearrange the long distance plant, built to fit one pattern of needs, to meet another set of demands brought about by rapid changes in calling. Any mass movement of people that tends to shift the population centers calls for extraordinary measures to meet telephone requirements.

In a thinly populated part of the country, a forest or plain with little telephone plant in it may within a few months be transformed into the equivalent of a large city by the establishment of a military training camp. This sudden shift of population takes large numbers of men away from the towns from which they usually make their telephone calls to a point where new telephone plant must be built to handle their calls. The plant serving their homes is now used but little by them and must be duplicated with similar plant at the new location. The fact that a large number of people have moved from one place to another has made it necessary not only to build new plant to serve them, but also has created for them a new need for calling and they make more calls than they would had they not moved.

BUSINESS CONDITIONS themselves sometimes change rapidly and the number of long distance calls may increase at a rate far greater than can be foreseen. Allowances are made for reasonable variations from the estimates of calls, but should the rate of growth in a locality change quickly to, say, twice the normal rate, it may be found extremely difficult to match the increase in calls with additions of long distance circuits, due to the time required to manufacture

and install new circuits. When such unforeseeable changes occur there may be periods when some callers must hang up the telephone after placing a call and wait for a circuit to become available. So well have the demands for service ordinarily been met that the American people have come to take it for granted that telephones and circuits will be available when they want to use them and that the service will be fast and accurate.

Dialing Long Distance Calls

JOHN'S CALL was handled manually by his long distance operator and the other operators along its path. To another place his long distance operator might have dialed the connection.* On dialed calls, the long distance operator dials a number for a circuit, just as John had dialed the long distance number. The tandem switches connect her to a circuit to H, further dialing brings her to K and L, after which she dials the called number. This service also is fast and accurate, and has technical advantages that will permit even faster, clearer, more accurate service as our country moves into its next stage of progress.

The time may come when it is possible for the customer to dial from one telephone to any other telephone in a very large area; but the magnitude of the problems, one of which is placing at the disposal of the calling party up-to-date information regarding the telephone numbers in distant places, makes it appear at present that the best long distance service will for a long time be furnished when an operator handles all calls to the more distant places.

There are many kinds of paths for long distance calls. Some are composed of just two wires, others use four wires, in other cases four wires provide ten or twelve paths. In one type of construction a tube with a wire in its center provides many hundreds of paths. Transoceanic and ship-to-shore paths use radio. Some paths are designed for manual operation, others for dialing. How many are required between two places? How shall they be routed? The answers to these questions are at the heart of the Bell System's responsibility for nation-wide service, and represent the part that telephone engineers play in the constant endeavor to provide clearer, quicker, and more convenient service to all.

OH YES, about John's call to Gramp! In spite of storm and busy wires the call went through while John remained at his telephone. Gram called Gramp to their telephone and that night he was on the train with his bag of heavy stones. There were diamonds among them and the war plant did not close.

And now Gram's knitting needles click a little faster as she listens while Gramp spins yarns to the kid up the way about his trip to Big Town and how he and John helped win the war.

* See "A Dial Switching System for Toll Calls, MAGAZINE, Winter 1943–44.

The Bell System's Manufacturing and Supply Organization, Now an Arsenal of Communication Equipment for Our Armed Forces, Marked Its 75th Anniversary in November

Western Electric's First 75 Years: A Chronology

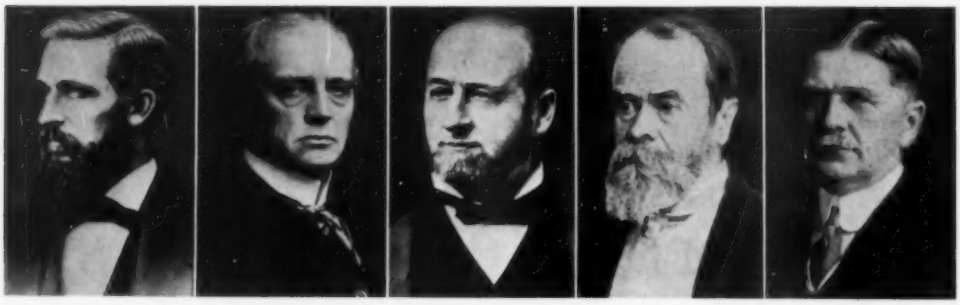
Frank H. Lovette

The Western Electric Company's 75th anniversary was observed throughout the Bell System last November, and the following pages constitute a brief outline of the company's history. Telephone people will find implicit the interdependence among Western Electric, Bell Telephone Laboratories, and the Associated Companies, in war no less than in peace; and will realize that much of Western Electric's present war production cannot be discussed in detail because nearly half of it consists of "restricted" items.

ON MANY a dark day of the War between the States, a visitor to the inner sanctum of the War Department at Washington might have found President Lincoln and Secretary Stanton standing in the wire room beside a brown-eyed, ruddy faced young Army Colonel, all three gravely scanning the telegraph register tape as it rolled out code messages from the battle fronts.

Sometimes the President and Secretary anxiously awaited decoding of those historic messages, a job the young Colonel, Anson Stager, readily accomplished, since it was he who had invented the secret cipher. Military authorities of the Confederacy had not deciphered it, and the war would end without their succeeding in doing so. When urgent messages had to be transmitted, Col. Stager frequently replaced one of the operators and sent them personally.

Col. Stager, then Chief of the United States Military Telegraphs, had been an operator since 1846. He was the first to receive by sound; he had devised both the common battery and long lines systems



ELISHA GRAY | ENOS M. BARTON | ANSON STAGER | FRANCIS R. WELLES | CHARLES E. SCRIBNER

Founders, builders, presidents of the Western

of telegraphy; and as field agent for major telegraph interests he had convinced the railroads of the necessity of the telegraph as a safety device, arranging pole and line rights of way along their tracks. He had been a principal negotiator in the consolidation of warring companies which united to form the Western Union Telegraph Company. His work with McClellan in establishing the first military field telegraph system had won him authority over all military communications.

The Young Telegrapher

A SIMILAR VISIT to the Military Telegraph Office at New York during this same period might have found there Enos M. Barton, a young operator barely out of his 'teens, who also was a marvel of telegraphic speed and accuracy. He handled press dispatches from the war zones. Despite his youth, he was already a veteran telegrapher who had started "pounding brass" at the age of 12. A young man of impressive appearance, he had the broad forehead and deep set eyes of the intellectual, and spent much of his spare time reading good books. After his long and laborious day, often longer because of double shifts or wire trouble, he attended New York University's night school to increase the education begun at the University of Rochester, where he had worked his way through Freshman year.

At the close of the war Col. Stager, retired as a Brigadier General, returned to Cleveland as Western Union's general superintendent.

Enos Barton was transfered to Western Union headquarters at Rochester, where he became chief operator. In his new job, he examined and tested new inventions in the field of telegraphy. In December, 1868, his friend and fellow telegrapher, young Tom Edison, came to Rochester to try out his newly invented double transmitter over a circuit between Western Union headquarters and New York City. This and similar experiences convinced Barton that a great unexplored field of invention and development awaited the application of human genius in the electrical communications industry.

About the time of the Edison test, Barton had another visitor. The

WILLIAM S. SMOOT | HARRY B. THAYER | CHARLES G. DUBOIS | EDGAR S. BLOOM | CLARENCE G. STOLL

Electric Company during its 75-year history

newcomer was George Shawk, who until a few weeks before had been foreman of Western Union's Cleveland repair shop. Shawk brought interesting news.

"I've bought the shop," he told Barton. "If I had you in Cleveland, we could do great things." He went on to describe his prospects for electrical repair work and the manufacture of fire and burglar alarms.

During this conversation Shawk disclosed that his shop was making models for the inventions of a former Oberlin College physics professor, Elisha Gray. "He wanted to go in with me," Shawk added, "but I turned him down. I told him I didn't want the shop entirely given over to his darned fool inventions, but right now he's our best customer."

The Enterprise Is Started

THAT MEETING had far-reaching results; for a few days later Rochester's chief operator Enos Barton resigned that post to embark on his first business venture: the purchase of a half interest in George Shawk's shop. The down payment was set at $700, and Barton had but $200; but a family friend endorsed his note for $500, and agreed to help further when the final payment came due. Barton's mother voluntarily placed a mortgage of $400 on their family home to help her son finance his undertaking.

As soon as the first of these arrangements had been completed, Barton departed for Cleveland. The day he arrived and went to work, doing everything from tidying up the office and keeping the books to handling correspondence and outside sales and helping the "hands" operate the foot lathes, marked the real beginning of the Western Electric Company.

The formation of the new firm of Shawk and Barton was announced in the *Journal of the Telegraph,* and the junior partner went to board at the home of Professor Gray. Their kindred interests developed an immediate friendship. Barton had a long range conception of expanding the business into a manufacturing plant which could meet the demands of the dawning electrical era, already freely predicted by men of science. Professor Gray's inventive genius projected plans of great diversity and

scientific acumen which in themselves were a challenge to the shop's facilities.

Both Gray and Barton knew General Stager, probably the most experienced electrical communications authority in the United States, and had his active encouragement. During a conference among the three men, a partnership was proposed, and Stager agreed to consult his lawyer. The next day, when the two younger men returned for his answer, he told them his lawyer had advised that "confidence in the character and abilities of his partners would be his only protection." That statement must have cast a shadow over the hopes of Gray and Barton, but in the next moment Stager told them he had that confidence, and would attest it materially. Accordingly, he advanced Professor Gray $2,500 with which to buy Shawk's half interest in the shop, and himself took an interest in the Gray printer telegraph. That was in April, 1869. He agreed to become an equal partner at such time as they could arrange to move the business to Chicago, and the agreement was consummated on November 18, 1869.

During the next two years the little firm enjoyed a rapid growth, gaining an enviable reputation for integrity and for quality workmanship. It manufactured telegraph apparatus, fire and burglar alarms, the Gray printer telegraph, and other electrical devices.

Western Electric Manufacturing Co.

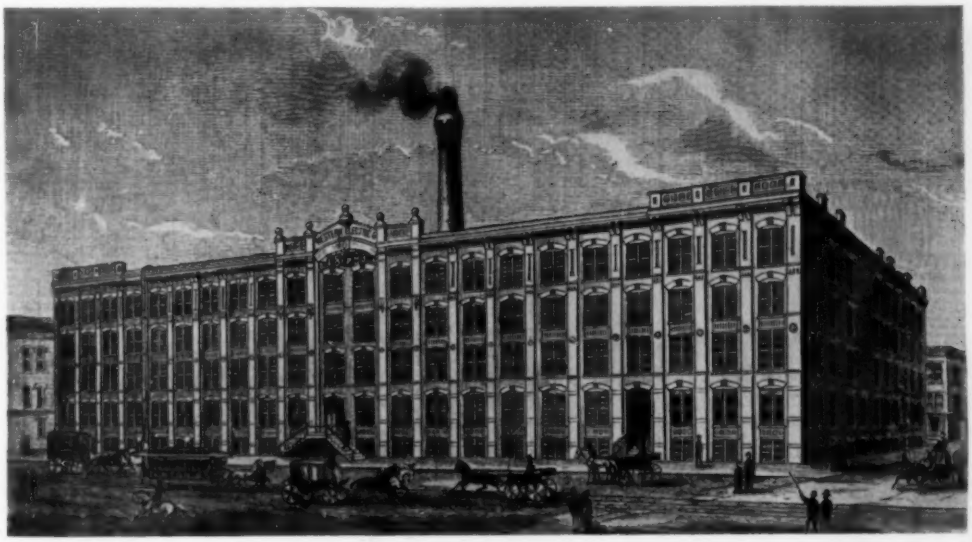
WHEN the great fire of 1871 ravaged Chicago, all seemed lost. But the fire was extinguished within two blocks of the shop, and the emergency service of Gray and Barton won public approval and brought unprecedented business in supplying equipment and installations to replace those lost in the fire. The service rendered the Western Union Telegraph Company in restoring its local communications system so won the admiration of that company's officials that three of them joined with Stager in financing and organizing in 1872 the $150,000 Western Electric Manufacturing Company as successor to Gray and Barton. The new corporation took over the assets and organization of the shop and also Western Union's Ottawa, Ill., shop. With this acquisition, Western Electric became the largest manufacturer of Western Union's Morse instruments and began greater production of Gray's printer telegraph.

Sales increased, new lines were added, and Western Electric co-designed the first commercial typewriter with the Remington Arms Company of Ilion, N. Y., and for a time acted as sales representatives marketing the first typewriters the Remington Co. manufactured. By 1876 the Western Electric trade mark had gained high prestige in the electrical equipment field, and at the Centennial Exposition held that year Western Electric won five first-class awards for devices of its own manufacture. In 1876 also, the same year in which Alexander Graham Bell received his famous telephone patent, the company began manufacturing the Edison "electric pen," predecessor of the modern mimeograph.

During these significant days of 1876, Barton hired two youngsters who were to have prominent parts in

shaping the future of Western Electric. They were F. R. Welles, the Company's first stenographer, and Charles E. Scribner, called the "boy inventor" because he was still in his teens and had already invented an improved telegraph relay. Before he was 21, young Scribner invented the jack switch which revolutionized telephone central office equipment and made the switchboard practical for York shop at 62–68 New Church Street.

It was believed by the then officials of the Western Electric Manufacturing Company that, as in the case of telegraph equipment, apparatus which accomplished the same purpose without detailed duplication did not infringe upon the patents for other apparatus of different fundamental design. But a patent controversy



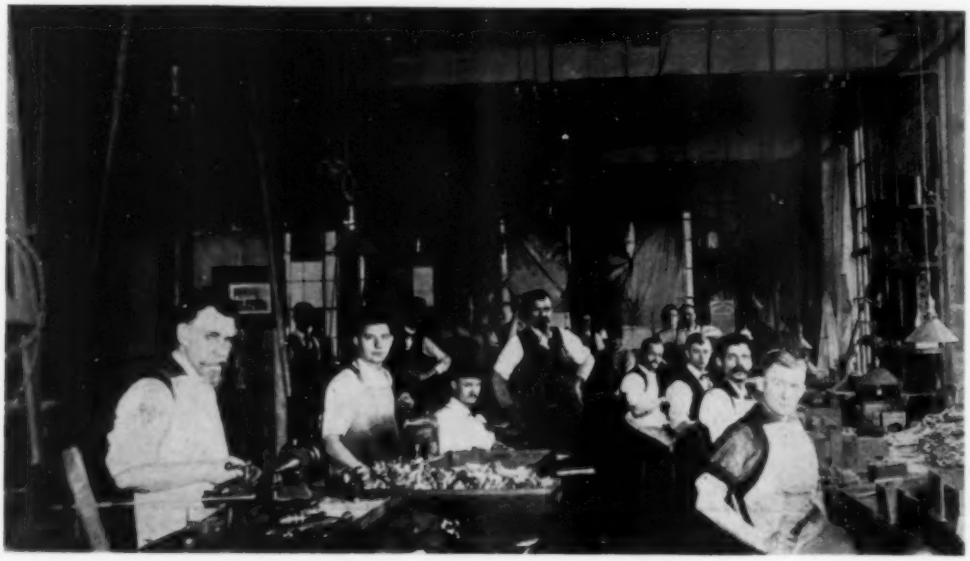
"Clinton Street," Western Electric's Chicago manufacturing plant from 1883 to 1908

interconnection of a great many subscribers.

Western Electric first began to manufacture telephones in 1877-78 under license of the Western Union Telegraph Company, which had bought the patents of Gray, Edison, and Dolbear. By 1879 Western Union Telegraph's telephone business was expanding so rapidly that it turned over to the Western Electric Manufacturing Company its New arose between Western Union and the Bell interests, and during the taking of testimony in the Dowd case of 1878–79 the controversy was settled by a compromise in which Western Union withdrew from the telephone business and surrendered its patents to the Bell Company in consideration of a 20 percent royalty upon all telephones rented in the United States during the tenure of existing patents.

The patent compromise left the

Western Electric Manufacturing Company greatly expanded but without a license to manufacture Bell telephones. Edison had just invented his incandescent lamp, and motors and generators heralded the dawn of the new power age. Gen. Stager and Enos Barton had wisely followed this progress, even counseling the inventors of the new electrical equipment developments. So they devoted a



A SCENE in the Clinton Street plant about 1895

portion of the company's facilities to making light and power apparatus, while continuing to manufacture switchboards and such telephone equipment as had not been involved in the patent controversy.

About 1881, it became apparent that future progress in the telephone art would depend upon high-quality standardized equipment. Since Western Electric had pioneered much electrical equipment and telephone apparatus, such as the Scribner switchboard, the company was regarded as the best qualified manufacturer to effect standardization of Bell telephone equipment. And so early in 1881, it was arranged between Gen. Stager, then Western Electric president, and Theodore N. Vail, at that time general manager of the American Bell Telephone Company, for the Bell organization to buy a minority interest in Western.

Enter the Bell System

IN NOVEMBER, 1881, Western Electric and Bell officials formed the $1,000,000 Western Electric Company of Illinois. The new corporation acquired full ownership of the Gilliland Electrical Manufacturing Co., of Indianapolis, and the Charles

Williams, Jr., Company, of Boston, and became the manufacturing unit of the Bell System. The year 1882 saw the signing of the manufacturing contract between Western Electric and the parent corporation.

Gen. Stager's distinguished career ended with his death in 1885. William S. Smoot, of the Remington Arms Company, succeeded him as Western Electric's president, but lived only one year. In 1886 Enos M. Barton, co-founder of the Company, became president. Western Electric had become one of the largest units in the Bell System, and its electrical manufacturing business had been extended to foreign countries under the supervision of that "first stenographer," F. R. Welles.

The announcement about 1890 that America would hold a World's Fair in Chicago in 1892 led the Bell System to undertake construction of a record-breaking long distance circuit over the 900 miles between New York and Chicago, to be ready for the opening of the Fair. The circuit was personally opened by Alexander Graham Bell during 1892 and was in full operation several months before the delayed World's Columbian Exposition opened in 1893.

A SCENE in the hand set department at the Hawthorne Works before the war

The Fair seems to have brought about an emphasis on sales activities which was the beginning of the Western Electric Company's organized selling, a new departure in its domestic system of merchandising. By 1900 Western's increasing business in power apparatus and electrical supplies had created for the company a substantial purchasing power, and it was evident that if the purchasing

power of the various telephone companies was combined with the purchasing power of the Western Electric Company, a substantial advantage in the buying for the whole System would result. This plan was first discussed by H. B. Thayer, manager of the company's New York branch, and Theodore Spencer, general superintendent of the Bell Telephone Company at Philadelphia; and the first supply contract was signed with the Philadelphia company in 1901. By 1913, supply contracts had been executed with all the associated telephone companies in the Bell System.

In 1897 the expansion of the business made it necessary to erect a new building at 463 West Street, to serve as the New York headquarters of the business and to house the New York shop. The power apparatus manufacturing business, located in Chicago, continued to expand, and numerous installations of important projects were made. Many new distributing houses were also opened.

"*Hawthorne*" *Is Started*

In 1902 Mr. Thayer was elected vice president, and in 1903 the construction of the first buildings of the great Hawthorne Works at Cicero, Ill., was authorized. In 1905 the power apparatus shops were moved from Clinton Street to Hawthorne. By this time the country had 4,000,000 telephones. Within a year Western Electric became the largest electrical manufacturing and distributing organization in the world, with sales of $65,000,000 in 1906. In that same year the company established a pension system which was one of the earliest in the manufacturing industry.

The sudden economic reversals of 1907 brought a financial panic which threatened the nation's banking system and all important industries. There was grave possibility that some telephone companies might have to suspend service.

In that crisis Messrs. Barton, Thayer, and Welles by brilliant services saved the company and helped relieve the strain upon other Bell System units hard hit by local banking difficulties. Mr. Thayer continued to furnish telephone supplies on an extended credit basis, Mr. Welles purchased American currency in Europe and brought it to this country to support the payroll, and Mr. Barton helped restore confidence by coming to New York and offering New York bankers reimbursement for borrowings in advance of due dates.

When, in 1907, Theodore N. Vail became president of the American Telephone and Telegraph Company, which had become the parent company of the Bell System in 1900, he found it necessary to reorganize not only its finances and general management but its engineering and research work as well. In the summer of 1907 the development personnel of the American Company, with their laboratory, which had been maintained in Boston, were removed to New York, and were merged with a similar group maintained in that city by the Western Electric Company. At the same time, a considerable part of Western's group of development engineers in Chicago was removed to New York to form a part of the new centralized unit at 463 West Street, under the direction of Chief Engineer C. E. Scribner.

Mr. Thayer was elected president of the Western Electric Company in 1908 and Mr. Barton became chairman of the board. The nation had well over 6,000,000 telephones and the Hawthorne plant had continued to expand through almost uninterrupted construction of additional buildings. Western Electric had carried the instruments of communication and many other electrical devices to far parts of the world.

By 1909 the increasing growth of the telephone manufacturing business indicated the wisdom of selling Western Electric's extensive power apparatus manufacturing business to the General Electric Company. Coincident with this sale, an agency arrangement for the distribution of General Electric power apparatus by Western was consummated.

W. E. in World War I

WORLD WAR I started in 1914, and the United States began to be involved in diplomatic incidents during 1915. In 1916 the engineers of the Western Electric Company and the A. T. & T. Co. conducted a mobiliza-

"DISTRIBUTION" at the old Philadelphia distributing house about 1904

tion test, in coöperation with the U. S. Navy, establishing a nationwide network of communications using telephone, telegraph, radio, and teletypewriters to communicate among points on this continent and ships deployed in adjacent waters. This system was used by the Government after we entered the war in April, 1917, and one of its offshoots was the first

ship-to-shore radio telephone equipment made by Western and supplied in quantity to the Navy.

THE USE OF airplanes as a military weapon in that war developed a need for means of communication between plane and ground, and Western Electric produced the first radio telephone equipment for this purpose. Mr. Thayer became a member of the U. S. Aviation Board. Another important Western Electric contribution to World War I was the production of large quantities of telephone equipment for the various Army cantonments built in many parts of the country. Western Electric's British company developed the "Nash Fish," a submarine detector for which its inventor, G. Howard Nash, was decorated by the British Government. Total sales of Western Electric equipment to the U. S. Government amounted to $31,918,000 during that war. That was thought to be a record no future emergency would ever see surpassed.

When the war ended, November 11, 1918, Western Electric again turned to the pursuits of peace. In 1919 Mr. Thayer was chosen as president of the American Telephone and Telegraph Company, succeeding Theodore N. Vail. Charles G. DuBois was elected Western Electric's president.

In 1922 a complete separation was effected between the Western Electric organizations handling Bell System telephone business and its electrical supply business. In 1923 construction was started on the great Kearny Works in New Jersey. The first production there in 1925 was of telephone cable. In that same year, Walter S. Gifford, who began his Bell System career with Western Electric in Chicago in 1904, became president of the American Telephone and Telegraph Company.

Western's Full-time Job

THE BELL SYSTEM'S rapid growth and the need for immense quantities of dial telephone apparatus and equipment made it evident that serving the System was a full time job for the Western Electric Company. Consequently, in 1925, Western incorporated the Graybar Electric Company, named in honor of Enos M. Barton and Elisha Gray, with Albert L. Salt as its president, for the purpose of segregating into a separate company its electrical supply business. In 1928 the common stock of this corporation was sold to its employees—a new departure in large corporation ownership. Western's interest in Graybar was thereafter represented only by preferred stock, the last of which was paid off and retired by Graybar in 1941.

During 1918 Western's foreign companies had been transferred to a newly organized subsidiary company called the International Western Electric Company. As an additional step to concentrate on the expanding Bell business, Western in the year 1925 sold the International Western Electric Company to the International Telephone and Telegraph Company, although retaining its interest in the Northern Electric Company, which serves the Bell Telephone Company of Canada.

As a measure to promote technical progress in communications, the Western Electric engineering department at West Street was incorporated

in December, 1924, as the Bell Telephone Laboratories. Its ownership is shared equally between the A.T.& T. Co. and Western Electric. Dr. Frank B. Jewett became its first president in 1925, and was succeeded in 1940 by Dr. Oliver E. Buckley.

As an outgrowth of telephone research, Bell Laboratories developed and Western produced, in 1926, equipment which brought to the world a notable advance in entertainment and education: the first commercially practicable talking motion pictures. The screen at last had become articulate and the long titles and printed dialogue disappeared.

The production of step-by-step and panel dial switching for the replacement of manual central office equipment continued. Later a third system, today's crossbar, was developed and placed in production.

In 1926 Mr. DuBois retired as Western Electric's president, and was succeeded by Edgar S. Bloom, then vice president of the A.T.& T. Co. Under his presidency Western Electric produced the equipment for the A.T.& T. Co. which resulted in the inauguration of commercial transatlantic radio telephone service in 1927. Under Mr. Bloom's guidance Western expanded its efforts in the production and installation of dial central office equipment. In 1929 the construction of a third great manufacturing plant, the Point Breeze Works, in Baltimore, Md., was commenced. The United States had

EFFICIENCY is the keynote of Western Electric's present 29 distributing houses

never seemed more prosperous, and the number of telephones had grown to 20,000,000.

But, as in 1907, economic forces halted the pace of this prosperity. In September, 1929, occurred a crisis on the New York Stock Exchange which was followed during the next four years by a series of economic and financial upsets, with many bank failures in Europe and this country. From this dark and trying period, Western Electric emerged stronger than at any previous time.

In 1931 the Bell System inaugurated its teletypewriter exchange service (TWX), whereby any subscriber in the TWX network could be switched to any other subscriber. To insure an adequate supply of equipment for this purpose, Western purchased the Teletype Corporation, Chicago, in 1930.

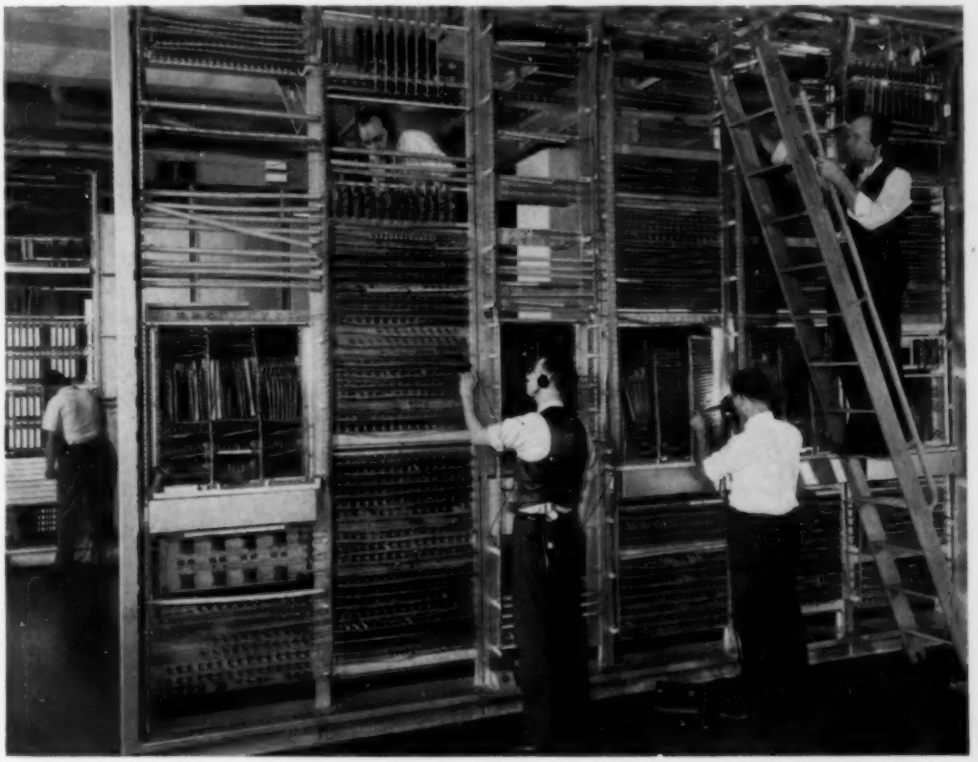
The following year Western acquired the Nassau Smelting and Refining Company at Tottenville, N. Y., in order to handle efficiently the increasing amounts of non-ferrous scrap materials removed from the Bell System plant.

In June, 1939, Western Electric was authorized by our Government to proceed with the manufacture of sub-

AN installation force, and a typical switchboard in process of being installed, about 1900

stantial quantities of airplane radio equipments. When Germany invaded Poland two months later, it was evident that Western's facilities were destined to play an important part in the coming world-wide struggle.

velopments of World War II. By mid-summer Germany had subjugated most of Europe. The British retreat from the Continent and the fall of France made it clear that Great Britain could not long withstand the German menace without enormous in-



WESTERN ELECTRIC installers at work on a modern crossbar central-office switching installation

The Threat of War

AT THE END of 1939 President Bloom retired, and Vice President Clarence G. Stoll was elected president of the Company on January 1, 1940.

The beginning of Mr. Stoll's administration witnessed alarming de-

dustrial aid.

The United States stepped up its defense program in September, 1940, with compulsory military training of men. This program called for a vast national chain of military camps and bases, for which the Associated Companies called on Western to provide many new and complex commu-

nication equipments. During this period Western Electric's experienced forces were busily engaged in the manufacture and installation of a great range of emergency and unusual services. They included telephone equipments for training camps, shipyards and industrial plants. More elaborate facilities were provided for the Army's mammoth Pentagon building in Washington, and new long distance telephone lines were furnished for installation throughout the country and to Alaska.

Meanwhile, men from Western Electric's manufacturing department scoured the land to find new plant facilities. Western needed more manufacturing space and hundreds of subcontractors, as the company was expected to serve as the "pilot" plant for the communications equipment industry.

Acute shortages of material threatened the country's war production. Western Electric purchasing agents went in search of new sources of raw material supply and had to find substitutes for many materials required by the Bell System to maintain its vital network of communications—since materials formerly used for this purpose had been commandeered for war use.

COURAGEOUS WORK of employees, as in many another emergency, saved the San Francisco distributing house from the fire of 1906

Those men who volunteered or had been drafted for the armed services had to be replaced, requiring employment of thousands of women for jobs ordinarily done by men. Since 1873 women had worked for Western, but usually on such lighter jobs as coil winding, assembly, relay adjustment, or clerical work. Now they were to do welding, drilling, carpentry, truck driving, even operate the giant cranes used to pick up cable

reels and heavy steel. Much other work of a technical nature, such as electrical testing, also had to be done by women. They had to be trained by thousands.

Daily the European war picture grew darker, but almost hourly Western Electric's production grew potentially larger as the employee training program became more effective. The Company's Government sales, which had been about $3,500,000 in 1940, climbed toward a 1941 volume of $41,000,000.

The battle lines of this world-wide war circled the earth. The United States and its Allies had need to coordinate offensives by air, land, and sea all over the world. The speed of the new mechanized warfare required communications equipment upon a hitherto undreamed of scale. Instantaneous and constant communications were imperative.

Reliable aviation radio transmitters and microphones had to be built to withstand the heat of a desert sun at one moment and the subzero temperatures of the stratosphere at another. Telephones and other instruments must endure the destructive effects of tropical fungi and in some cases complete immersion in salt water.

The United States and her Allies needed telephones, field switchboards, cable; radio telephone sets for tanks, planes, and ships; and other apparatus in enormous quantities throughout the world.

In 1942 Western Electric answered these needs with production which was reflected in sales to the Government of $309,000,000. In 1943 they reached $596,000,000. The Company's total sales, including sales to the Bell System of materials essential to war activities, amounted to $557,000,000 in 1942 and $700,000,000 in 1943.

Arsenal of Communications

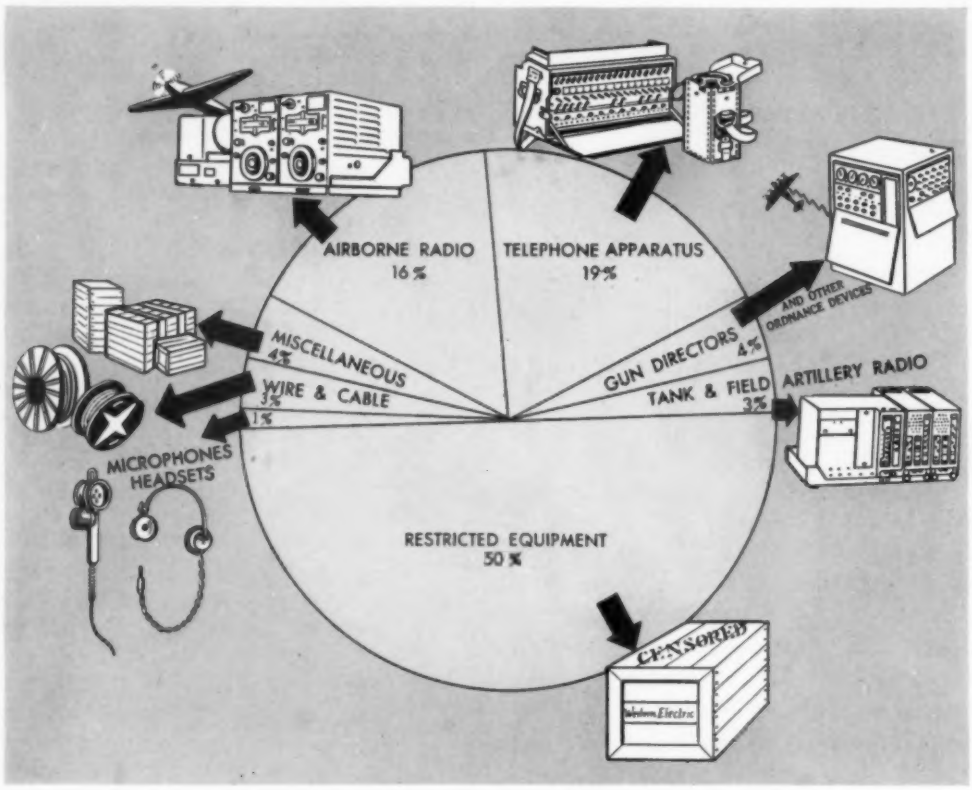
BEGINNING with the present war effort and up to the end of 1944, the men and women of Western Electric (and women now constitute more than half the force) had produced:

58,000 miles of Spiral-4 cable.
2,912,000 miles of wire in exchange cable of various sizes.
909,000 miles of wire in toll cable of various sizes.
22,700 miles of field wire.
Packaged "C" carrier equipments with a value of $22,000,000.
601,135 airplane radio receivers.
425,545 airplane radio transmitters.
46,657 combination airplane receivers and transmitters.
1,299,993 head sets for aviators and tank crews.
1,441,377 microphones.
Large quantities of various types of Radar.
Electrical gun directors.
Thousands of teletypewriters, including many adapted to radio.
22,800 switchboard positions of 22 varieties. (This quantity does not include those furnished telephone companies for installation in the Pentagon Building and in the hundreds of home-front military bases and war factories.)

These production statistics provide only a partial index to this war production, because about half of it is now the manufacture of "restricted" weapons, about which no slightest detail may be mentioned. However, as some indication of the nature of Western's collaboration and that of Bell Telephone Laboratories with the Government, it can be told that on

January 1, 1943, there were *92 major war projects* on Western's books. In 50 out of the 92 projects the devices were suggested to the Government by Western Electric and Bell Laboratories. In 78 the Bell Laboratories did the research development. In 79 they furnished the production design, and of all 92 projects Western was the manufacturer.

Today Western Electric products are helping our fighting forces turn the tide of battle on all the world's fighting fronts. In 1944 its sales to the Government were more than $788,000,000. In addition, during 1944 Western Electric's sales to the Bell System amounted to more than $120,000,000, practically all of which is applicable to the war effort. For the five year period 1940 to 1944 inclusive, the company's total sales to the Government amount to more than $1,700,000,000—which exceeds total sales to all customers during the first 50 years of its existence. Western Electric has met schedules which looked humanly impossible to meet. Nineteen of the 29 distributing houses converted repair shop facilities



THESE major items made up Western Electric's more than $788,000,000 of sales to the Government in 1944

to assist the three major Works. The company has leased 22 satellite plants in 15 cities, and has made subcontracts and other purchase arrangements with nearly 15,000 subcontractors and suppliers.

Western Electric's history has been inseparable from the record and growth of these United States. Seventy-five years ago a dozen highly skilled craftsmen competed for superiority of workmanship amid the quaint atmosphere of the Gray and Barton shop. That little band has grown into the present Western Electric family of 95,000, with activities almost as diverse as industry itself.

Diverse as are these war-time activities, Western Electric's responsibilities focus, in times of peace, almost entirely on its three-fold job as manufacturing, purchasing, and supply unit for the Bell System. From its factories and through its distributing houses it makes available the innumerable items out of which the telephone plant is constructed, and at the distributing houses used equipment is also repaired and reconditioned. Its skilled installation forces put in place and test the System's new central-office equipment through which the connection of telephone lines is accomplished.

OF 75 years of history, more has been omitted from the foregoing pages, obviously, than they have been able to tell. Implicit are Western Electric's accomplishments in public service for many years as first an independent manufacturer and then for 63 years an integral part of the Bell System. In the present struggle, the company is the world's largest producer of communications and electronic equipment for war, and Western Electric's men and women are making every day an incalculable contribution to Allied victory.

WE HAVE SEEN a nationwide poll which indicates that the public thinks big business has made big money out of the war. We doubt if that is true. We think the figures after renegotiation and taxes will show that never was so much produced for so small a profit.

But whether that is right for all big industry or not, we do know the Bell System has not profited by the war. We have never before handled as much business as we are handling now, and our earnings on the money in the business are lower than they have been in thirty years—except for the four worst years of the depression.

Not only are we not profiteering on the war, we are not making even normal earnings. When the war is over, we want to do our full part in providing the prosperity and jobs and opportunities which we all hope to see in this country. This will mean a lot of work for a lot of people—and an ever-improving telephone service for all.

An announcement on The Telephone Hour radio program.

For the Record

A selected list of happenings, of System interest, occurring between Nov. 1, 1944, and Feb. 28, 1945

RATES for overseas telephone service to Hawaii from about two-thirds of the states of this country were reduced on November 1. Rates to the Bahamas from about one-third of the states, and to Jamaica from anywhere in the country, were reduced on the same date.

On December 1, rates for overseas telephone service from this country to Bermuda were reduced.

By a resolution passed December 29, the National War Labor Board established a National Telephone Panel. The Panel, unless the Board otherwise directs, shall have jurisdiction of all voluntary and dispute cases involving the telephone industry. The Panel shall have authority to refer to a Regional War Labor Board any voluntary case which it deems can be more effectively handled by a Regional Board.

The Senate confirmed on January 18 the nomination of Paul A. Porter, former director of publicity for the Democratic National Committee, as a member of the Federal Communications Commission. Mr. Porter will serve as Chairman of the FCC.

Who's Who & What's What

(*Continued from page 211*)

the called telephone, the telephone engineer combines technical skill with common sense. From 1916 to 1922 RALPH MABBS spent most of his waking hours in the long distance offices at St. Louis and other cities of the southwestern part of the country as assistant traffic chief and division traffic engineer for the Long Lines Department. In 1923 he came to the O. and E. Department of A. T. & T., where he adapted the principles of trunking to the "coefficient" method of measuring operator work volumes now in use throughout the Bell System and in some foreign countries. The year 1926 found him again in traffic field work, in the Upstate Area of the New York Telephone Company. In 1929 he came back to the O. and E. Department, where he has since been engineer, toll traffic engineer, traffic methods engineer, and traffic facilities engineer.

THE PLACE of the Western Electric Company in the Bell System scheme of things—as manufacturer, supplier, installer of central-office equipment—is so generally understood that FRANK H. LOVETTE has been able to devote his pen to many of the less well-known aspects of his company's 75-year history. He joined Western Electric in 1943, where his post is now that of Historian. His previous career includes being, among other things, publisher of a daily newspaper in the south, executive officer of the old Federal Radio Commission, secretary to a member of congress, editor of a radio journal, a contributor to magazines, and the author of three books.